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RESEARCH MEMORANDUM

for the

U. S. Air Force

LONGITUDINAL AERODYNAMIC CHARACTERISTICS OF VARIOUS

CONFIGURATIONS OF A REVISED 1/22-SCALE MODEL

OF THE REPUBLIC F-105 AIRPLANE AT MACH

NUMBERS OF 1.41 AND 2.01

COORD. NO. AF-163

By Gerald V. Foster

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NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS

WASHINGTON

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SUMMARY

An investigation of a 1/22-scale model of the Republic F-105 airplane conducted in the Langley 4- by 4-foot supersonic pressure tunnel has been extended to determine the static longitudinal aerodynamic characteristics of a revised configuration for Mach numbers of 1.41 and 2.01. In the present investigation all configurations of the revised model incorporated a 45° sweptback wing of aspect ratio 3.2 and twin-root supersonic inlets. The model revisions included the following: (1) a lengthened fuselage, (2) a relocated canopy, (3) a contoured fuselage afterbody, (4) a ventral fin, and (5) an enlarged vertical tail. The investigation included the effects of various arrangements of external stores, a photoreconnaissance nose, duct air-bleed ports, and fully deflected dive-brake flaps.

The revised model with a horizontal-tail incidence of -3° exhibited a minimum drag coefficient of approximately 0.037 for Mach numbers of 1.41 and 2.01. A comparison of the drag characteristics of the revised model and the original model equipped with transonic inlets at a Mach number of 1.41 indicated that the drag of the revised model was substantially lower than the drag of the original model. With the horizontal tail of the revised model at an incidence angle of -24°, values of trim lift coefficient of approximately 0.475 and 0.675 were obtained at an angle of attack of 13° for Mach numbers of 2.01 and 1.41, respectively. The maximum trim lift-drag ratio was 4.3 for a Mach number of 1.41.

INTRODUCTION

At the request of the United States Air Force, an investigation of the aerodynamic characteristics of the Republic F-105 airplane configuration has been undertaken by the National Advisory Committee for Aeronautics. This airplane has a 45° sweptback wing having an aspect ratio of 3.2. References 1 to 6 present the aerodynamic characteristics of various configurations of this airplane at subsonic, transonic, and supersonic speeds. References 5 and 6 indicate some improvement in the drag level and directional stability were obtained with certain revised configurations. These modifications consisted primarily of changes in the fuselage geometry and in the case of reference 6 were incorporated with a modified wing of aspect ratio 3.7.

This paper presents results of additional tests in the Langley 4- by 4-foot supersonic pressure tunnel to determine the longitudinal stability and control characteristics at Mach numbers of 1.41 and 2.01 for a revised configuration of the Republic F-105 airplane equipped with a wing of aspect ratio 3.2. The revised configuration as compared with the original configuration of reference 3 incorporated (1) a lengthened fuselage, (2) a relocated canopy, (3) a contoured fuselage afterbody, (4) a ventral fin, and (5) an enlarged vertical tail. Included in the paper are results showing the effects of a photoreconnaissance nose, various arrangements of external stores, duct air-bleed ports, and fully deflected dive-brake flaps. In order to evaluate the overall effect of the revisions on the longitudinal characteristics at a Mach number of 1.41, results obtained with the original configuration equipped with transonic inlets are included.

SYMBOLS

The data are referred to the stability axes with the reference center-of-gravity (moment center) located at the quarter chord of the mean aerodynamic chord and have been reduced to nondimensional coefficients which are defined as follows:

C_L	lift coefficient, Lift/qS
C_D'	external drag coefficient, Drag/qS
C_m	pitching-moment coefficient, Moment/$qS\bar{c}$
S	area of basic wing (excluding inlets), 0.795 sq ft

b	wing span, 1.59 ft
c	chord, ft
$\bar{c}$	mean aerodynamic chord, 0.52 ft
q	free-stream dynamic pressure, lb/sq ft
W/S	wing loading, lb/sq ft
L/D	lift-drag ratio, C_L/C_D
M	free-stream Mach number
α	angle of attack of fuselage reference line, deg
i_t	angle of incidence of chord plane of horizontal tail with respect to fuselage reference line, deg
Δa_n	increment of normal acceleration, g
ϵ_e	effective downwash angle, deg
$\partial C_m/\partial i_t$	horizontal-tail effectiveness
dC_m/dC_L	rate of change of pitching-moment coefficient with lift coefficient

MODEL AND APPARATUS

The geometric characteristics of a revised and original configuration of a 1/22-scale model of the Republic F-105 airplane are presented in figure 1 and in table I. Photographs of the model configurations are presented in figure 2.

The model configurations, designated "revised" and "original" herein, differ because of changes in the fuselage and inlet geometry and vertical-tail area.

Both configurations were equipped with a wing having 45° sweepback at the quarter-chord line, an aspect ratio of 3.2, and a taper ratio of 0.468. The wing was constructed with an NACA 65A003.7 airfoil section at the tip and NACA 65A005.5 airfoil sections at the station 0.38b/2 from the plane of symmetry. The wing was positioned slightly above the fuselage reference line.

The fuselage of the revised model differed from that of the original model namely by (1) a lengthened forebody, (2) a more forward located canopy, and (3) a contoured afterbody accomplished by the addition of a bump. (See fig. 1.)

Both models were equipped with open twin-root inlets ducted to a single exit at the base of the fuselage. The duct system incorporated a boundary-layer diverter with a wedge half angle of 49° connected to the air-bleed port shown in figure 1. The revised model had supersonic inlets (fig. 2(a)), whereas the original model had transonic inlets (fig. 2(b)). An all-movable horizontal tail was mounted below the extended chord plane of the wing. The vertical tail of the revised model had approximately 32 percent more area than that of the original model. Both models were equipped with a ventral fin. The dive-brake flaps and duct air-bleed port are shown in figure 1; the gun blisters and external stores are shown in figures 2(a) and (3), respectively. The forces and moments acting on the model were measured by means of a six-component internal strain-gage balance attached to a sting.

TEST

Test Conditions and Procedure

The tests were conducted in the Langley 4- by 4-foot supersonic pressure tunnel at Mach numbers of 1.41 and 2.01 with a stagnation pressure and temperature of 5 pounds per square inch absolute and 100° F, respectively. The dewpoint was maintained slightly below -25° F so that no significant condensation effects were encountered. The relative low stagnation pressure of the test was dictated by limitations of the strain-gage balance. The Reynolds number based on the mean aerodynamic chord was 7.9×10^5 for $M = 1.41$ and 6.4×10^5 for $M = 2.01$. Forces and moments were measured through a range of angles of attack from -6° to approximately 19° at a sideslip angle of 0°.

Corrections and Accuracy

The angles of attack have been corrected for deflection of the strain-gage balance and the sting under load. Base-pressure measurements were made and the drag coefficients were adjusted to correspond to free-stream static pressure at the base. The internal pressure of the model was measured and corrections for a buoyant force on the strain-gage balance have been applied to the drag results. The internal drag was determined from the change in momentum from free-stream conditions to the measured conditions at the duct exit. The base drag, buoyant force, and

internal drag have been subtracted from the total-drag measurements so that a net external drag was obtained. The mass-flow ratios for the transonic and supersonic inlets were about 0.76 and 0.80, respectively.

The estimated errors in the various measured quantities are as follows:

Quantity	M = 1.41	M = 2.01
C_L	±0.0045	±0.0056
C_D'	±0.0011	±0.0013
C_m	±0.0020	±0.0026
α, deg	±0.1	±0.1
i_t, deg	±0.1	±0.1
M	±0.01	±0.01

PRESENTATION OF RESULTS

The results are presented in the following manner:

Figure

DISCUSSION

Characteristics of Revised Model

Basic configuration.- The longitudinal aerodynamic characteristics of the revised model with various horizontal-tail settings and with the horizontal tail removed (figs. 4 and 5) have been used to determine the longitudinal characteristics for trim at $M = 1.41$ and $M = 2.01$ (fig. 6). The minimum drag coefficient obtained at $i_t = -3^\circ$ is approximately 0.037 for $M = 1.41$ and $M = 2.01$. The results indicate that, with the horizontal-tail incidence of -24°, maximum values of trim lift coefficient of approximately 0.475 and 0.675 were obtained at an angle of attack of approximately 13° for $M = 2.01$ and $M = 1.41$, respectively. The maximum trim lift-drag ratio was 4.3 for $M = 1.41$ and 3.7 for $M = 2.01$.

The effectiveness of the horizontal tail as measured by $\partial C_m/\partial i_t$ decreased from -0.0160 for $M = 1.41$ to -0.0090 for $M = 2.01$. (See fig. 7.) The decrease in $\partial C_m/\partial i_t$ is primarily associated with Mach number effects on the tail lift characteristics. It may be noted that at $M = 1.41$ the horizontal-tail effectiveness decreases for values of i_t greater than 14°.

The values of effective downwash angle (fig. 7) determined from the tail-on and tail-off pitching-moment characteristics indicate that the tail operates in an effective upwash field.

An indication of the maneuverability at $M = 1.41$ and $M = 2.01$ may be obtained from the variation of Δa_n with altitude presented in figure 8. The term a_n defines the normal acceleration due to a rapid change in angle of attack and is determined in this case by the ratio of the maximum lift coefficient available for a horizontal-tail incidence of -24° to the lift coefficient required for level flight at a specific wing loading and altitude. The increment Δa_n hence represents a change in normal acceleration from a level-flight condition. For convenience, the variation of lift coefficient required for level flight at various wing loading with altitude has been included in figure 8. These results indicate that greater maneuverability is available at $M = 2.01$ throughout the altitude range because the lift coefficient required for level flight at a given altitude decreases at a more rapid rate with Mach number than does the maximum lift coefficient available for a horizontal-tail incidence of -24°.

Effect of stores.- The addition of stores caused a relatively small change in the lift-curve slope and no appreciable change in the longitudinal stability at $M = 1.41$. (See fig. 9.) The wing stores introduced an incremental drag coefficient at $C_L = 0$ of 0.0154 which is approximately twice that realized with the body store or equal to approximately 40 percent of the drag coefficient of the store-off configuration at $C_L = 0$. Comparison of the drag increase at $C_L = 0$ due to individual stores with that due to stores in combinations indicate that the incremental drag coefficient of the wing stores in combination with the body store exceeds the summation of incremental drag coefficients of the wing stores tested individually on the model by approximately 0.0040. The wing stores in combination with the body store resulted in the largest decrease in the maximum untrimmed lift-drag ratio; this decrease amounted to a decrease from 5.0 to 4.1 with the addition of these stores (fig. 10).

Effect of dive-brake flaps.- The results presented in figures 11 and 12 indicate that, with the dive-brake flaps in a full-open position, the drag coefficient of the model was increased through the lift-coefficient range approximately 0.060 at $M = 1.41$ and approximately 0.040 at $M = 2.01$. These flaps had no appreciable effect on the longitudinal stability but, as might be expected when their location is considered, these flaps adversely affect $\partial C_m/\partial i_t$ and result in a decrease in trim lift coefficient. For example, the decrease in trim lift coefficient for $i_t = -8^{\circ}$ was approximately 0.055 for $M = 1.41$ and $M = 2.01$.

Effect of forebody modifications, gun blisters, and duct air bleed.- The modification of the forward part of the fuselage to resemble the photoreconnaissance version of the airplane or the addition of gun blisters caused only a slight increase in the drag characteristics (fig. 14). Figure 15 indicates that the duct air-bleed ports had no significant effect on the longitudinal aerodynamic characteristics of the model.

Characteristics of Original Model

Comparison of original and revised model.- The longitudinal aerodynamic characteristics for $M = 1.41$ of the original model equipped with transonic inlets for various horizontal-tail incidence angles are presented in figure 16. The results presented in figures 17 and 18 show a comparison of the longitudinal stability and trim characteristics of the original and revised model at $M = 1.41$. In general, the revised model had a substantially lower drag through the lift-coefficient range.

Effect of dive-brake flaps.- Figures 19 and 20 indicate that dive-brake flaps were an effective means of increasing the drag for the original model throughout the range of lift coefficients investigated. For example, at $C_L = 0$, the drag-coefficient increment due to the flaps amounted to 0.066 and is approximately equal to that obtained with these flaps on the revised model (fig. 11). The pitching-moment characteristics (fig. 19(b)) indicates these flaps had an adverse effect on the horizontal-tail effectiveness and resulted in small negative trim changes.

CONCLUSIONS

From the results of an investigation of the longitudinal aerodynamic characteristics of a revised 1/22-scale model of the Republic F-105 airplane equipped with twin-root supersonic inlets at Mach number of 1.41 and 2.01 in the Langley 4- by 4-foot supersonic pressure tunnel, the following conclusions may be drawn:

(1) The revised model exhibited a minimum drag coefficient of approximately 0.037 for a Mach number of 1.41 (tail incidence of -3°) which was substantially lower than the drag of the original model equipped with transonic inlets. Increase in Mach number from 1.41 to 2.01 had no significant effect on the drag of the revised model. With a horizontal-tail incidence of -24°, values of trim lift coefficients of approximately 0.475 and 0.675 were obtained at an angle of attack of 13° for Mach numbers of 2.01 and 1.41, respectively. The maximum trim lift-drag ratio was 4.3 for a Mach number of 1.41 and 3.7 for a Mach number of 2.01.

(2) For a given wing loading and altitude, the maneuverability would be markedly greater at a Mach number of 2.01 than at a Mach number of 1.41.

(3) The addition of the wing stores introduced an incremental drag coefficient of approximately 0.016 at a lift coefficient of 0 which was about twice that realized with the body store. The addition of the wing stores in combination with the body store resulted in a decrease in the maximum untrimmed lift-drag ratio from approximately 5.0 to 4.1 at a Mach number of 1.41.

(4) The dive-brake flaps were an effective means of increasing the drag without causing significant changes in the stability characteristics. These flaps adversely affected the horizontal-tail effectiveness resulting in a small negative trim change. These flaps provided an average incremental drag coefficient through the lift-coefficient range of 0.060 at a Mach number of 1.41 and 0.040 at a Mach number of 2.01.

(5) The photographic nose or the addition of gun blisters caused only a slight increase in the drag characteristics.

Langley Aeronautical Laboratory,
National Advisory Committee for Aeronautics,
Langley Field, Va., May 2, 1956.

Gerald V. Foster
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Approved: L. J. Turner Jr.
for John V. Becker
Chief of Compressibility Research Division

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6. Spearman, M. Leroy, Driver, Cornelius, and Robinson, Ross B.: Aerodynamic Characteristics of Various Configurations of a 1/22-Scale Model of the Republic F-105 Airplane at a Mach Number of 2.01. NACA RM SL54J08, U.S. Air Force, 1954.

TABLE I.- GEOMETRIC CHARACTERISTICS OF 1/22-SCALE MODEL OF REPUBLIC F-105 AIRPLANE

Wing:	
Aspect ratio	3.2
Span, ft	1.59
Area (excluding inlets), sq ft	0.795
Taper ratio	0.468
Sweep at quarter-chord line, deg	45
Dihedral, deg	-3.5
Twist, deg	0
Incidence, deg	0
Airfoil section at station 0.38b/2	NACA 65A005.5
Airfoil section at theoretical tip	NACA 65A003.7
Mean aerodynamic chord, ft	0.52
Horizontal tail:	
Aspect ratio	3.06
Span, ft	0.76
Area (includes fuselage)	0.19
Taper ratio	0.46
Sweep at quarter-chord line, deg	45
Airfoil section, root	NACA 65A006
Airfoil section, tip	NACA 65A004
Mean aerodynamic chord, ft	0.26
Tail length from $\bar{c}/4$ of wing to $\bar{c}/4$ of tail, ft	0.94
Dihedral, deg	0
Vertical tail (revised):	
Aspect ratio	1.73
Span (to body center line), ft	0.59
Area (to body center line), ft	0.20
Taper ratio	0.32
Sweep at quarter-chord line, deg	45
Mean aerodynamic chord, ft	0.37
Tail length from $\bar{c}/4$ of wing to $\bar{c}/4$ of vertical tail	0.75
Vertical tail (original):	
Aspect ratio	1.59
Span (to body center line)	0.50
Area (to body center line), sq ft	0.155
Taper ratio	0.365
Sweep at quarter-chord line, deg	45
Airfoil section, inboard	NACA 65A006
Airfoil section, tip	NACA 65A004
Mean aerodynamic chord, ft	0.33
Tail length from $\bar{c}/4$ of wing to $\bar{c}/4$ of vertical tail	0.79
Ventral fin (revised):	
Area, sq ft	0.026
Fuselage (revised):	
Length	2.81
Fuselage (original):	
Length	2.74
Width, maximum, ft	0.199
Depth, maximum, ft	0.296
Frontal area, sq ft	0.051
External stores:	
Wing store:	
Length, ft	0.85
Diameter, maximum, ft	0.11
Frontal area, sq ft	0.01
Body store:	
Length, ft	1.25
Diameter, maximum, ft	0.17
Frontal area, sq ft	0.02

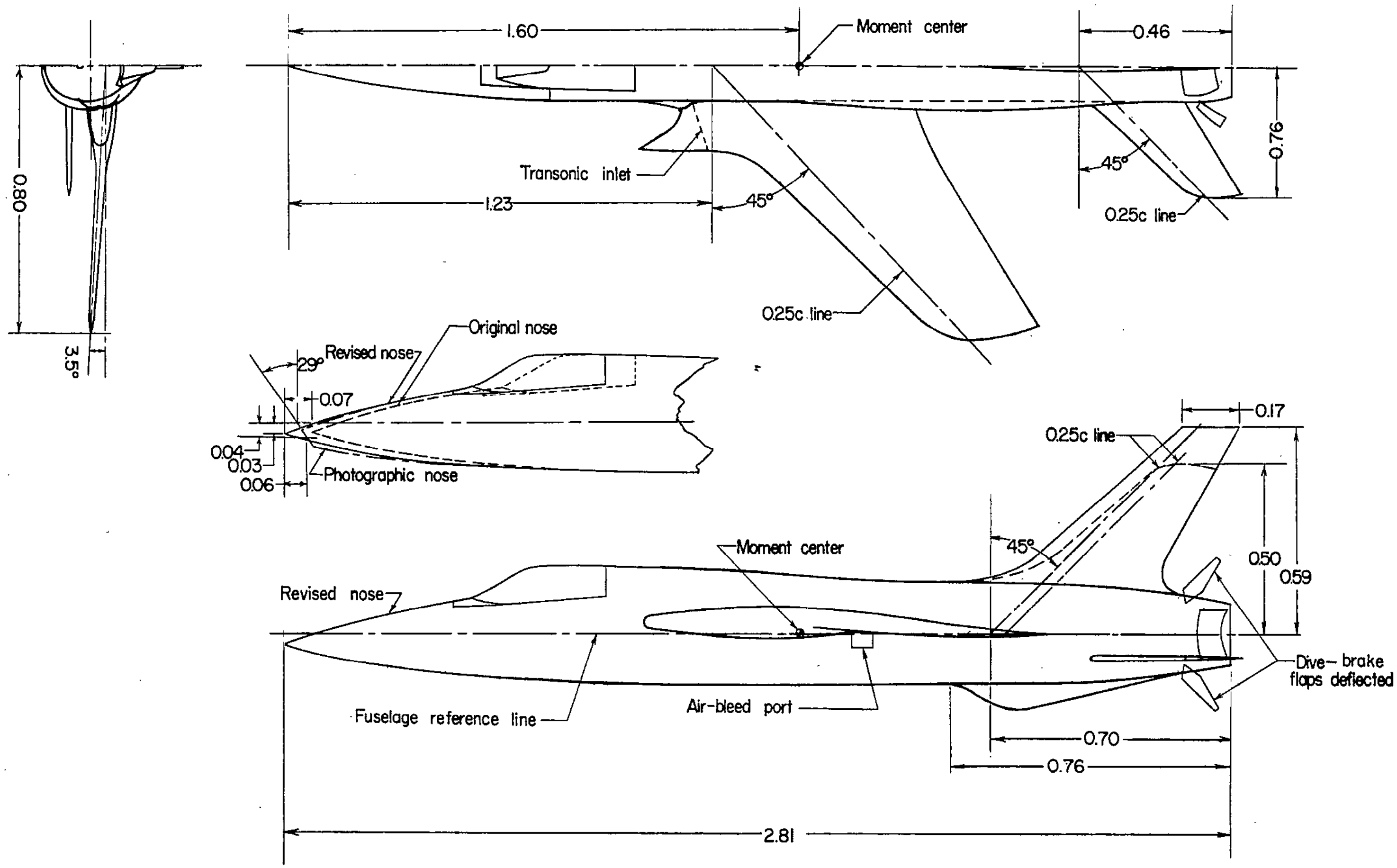
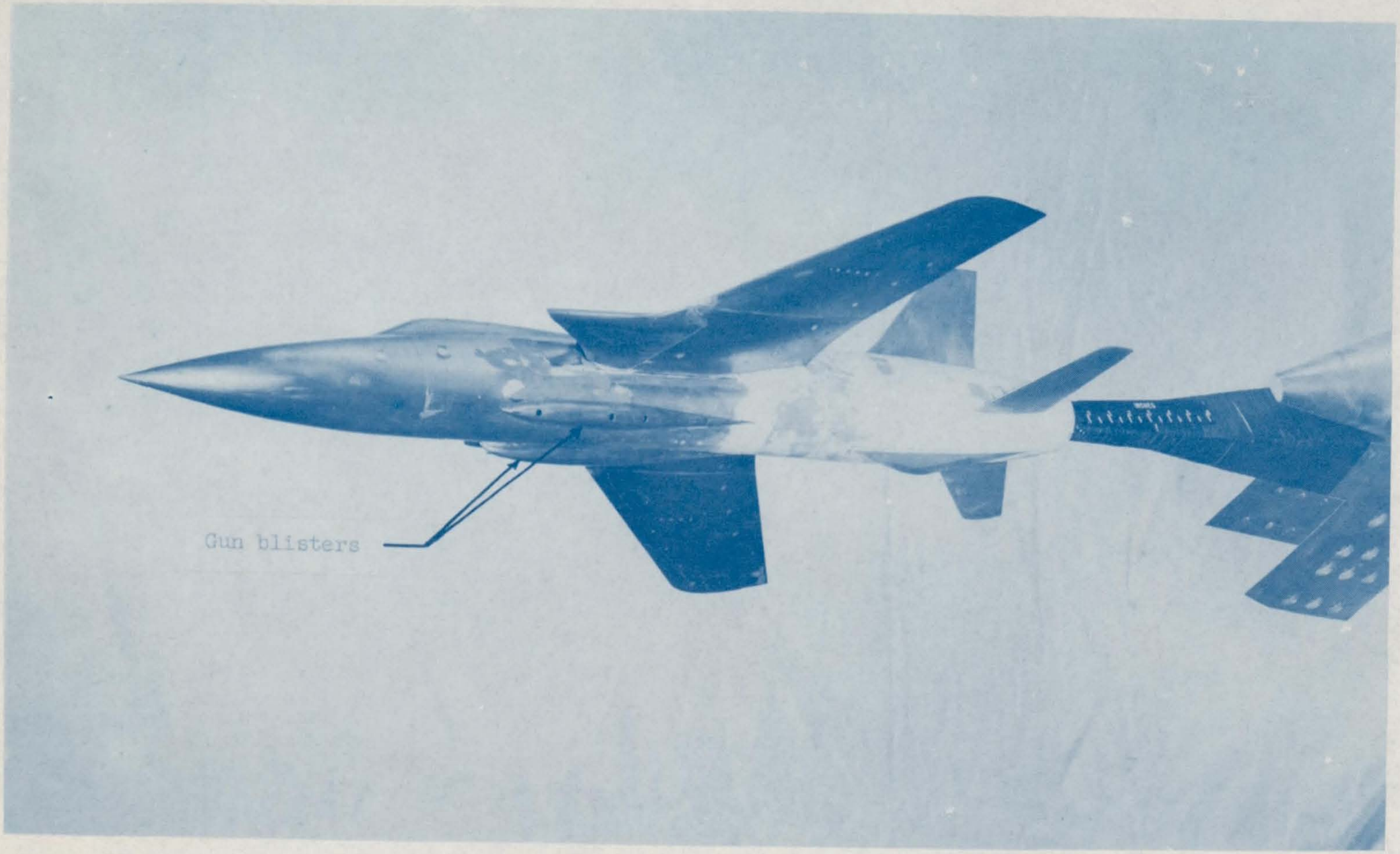
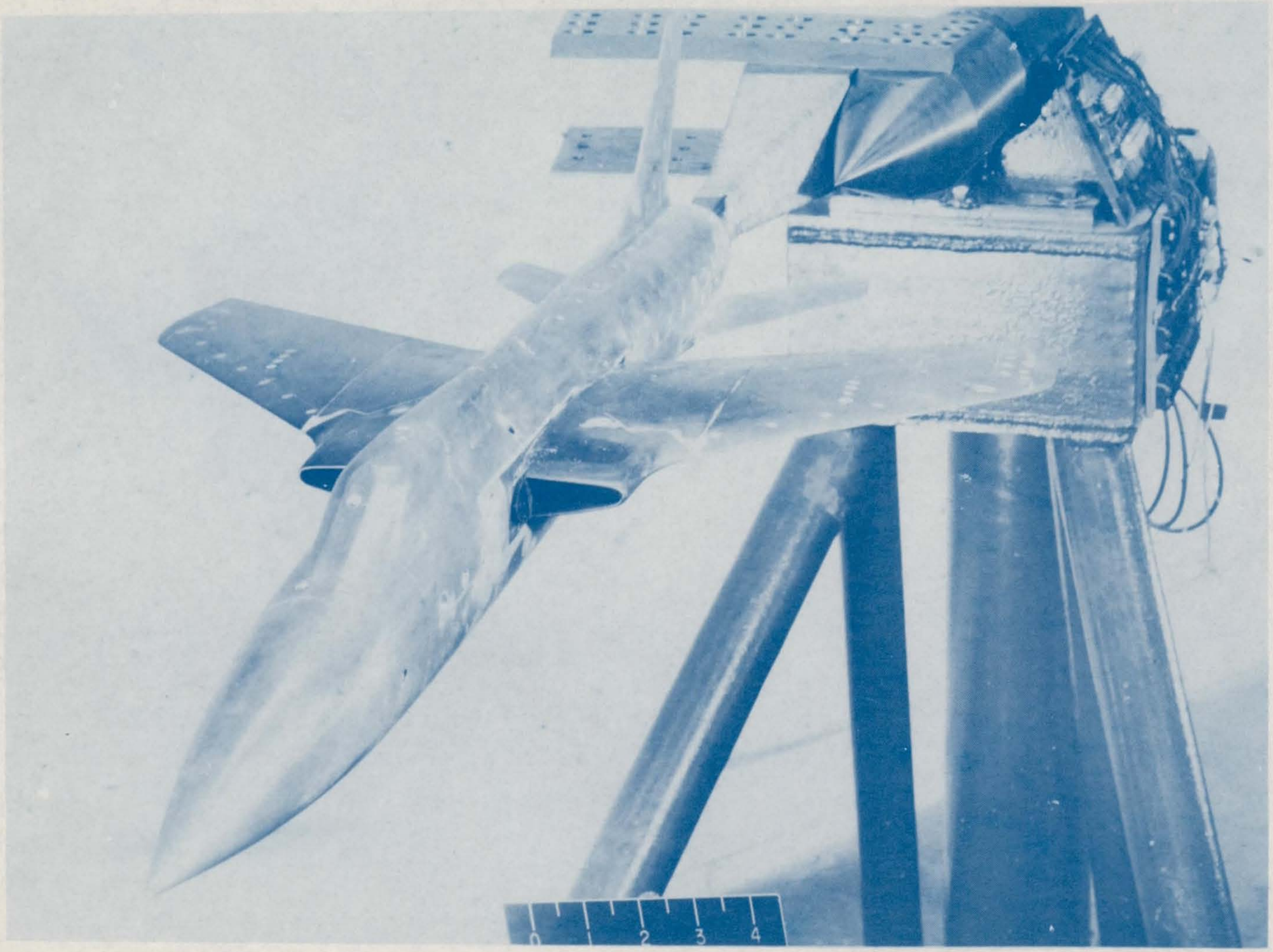


Figure 1.- Geometric characteristics of a revised 1/22-scale model of Republic F-105 airplane. Dash lines indicate original model with transonic inlet. All dimensions in feet unless otherwise noted.



(a) Supersonic inlets on. L-91359.1

Figure 2.- Photograph of model.



(b) Transonic inlets on. L-88916

Figure 2.- Concluded.

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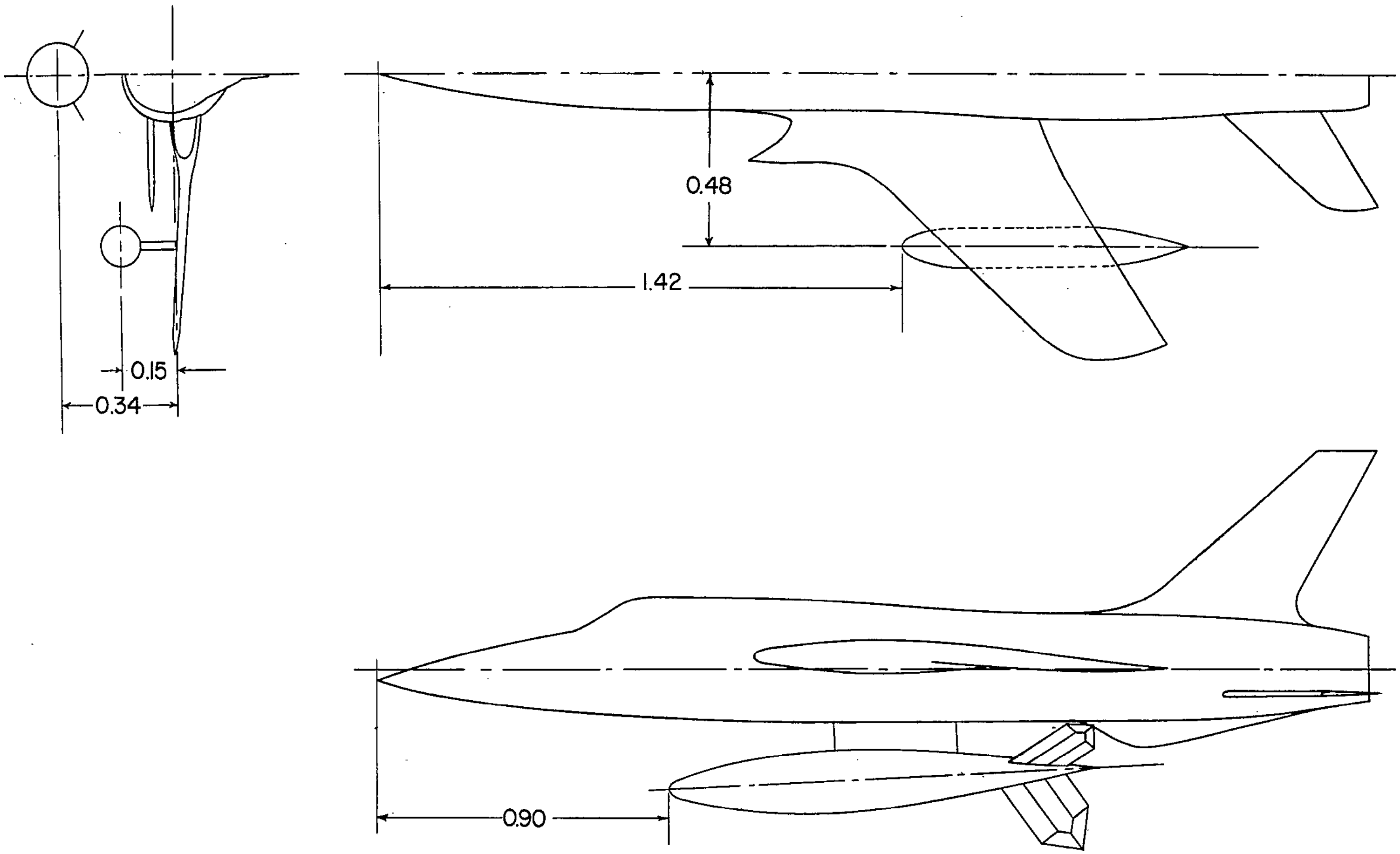

Figure 3.- Sketch showing location of external stores. All dimensions are in feet.

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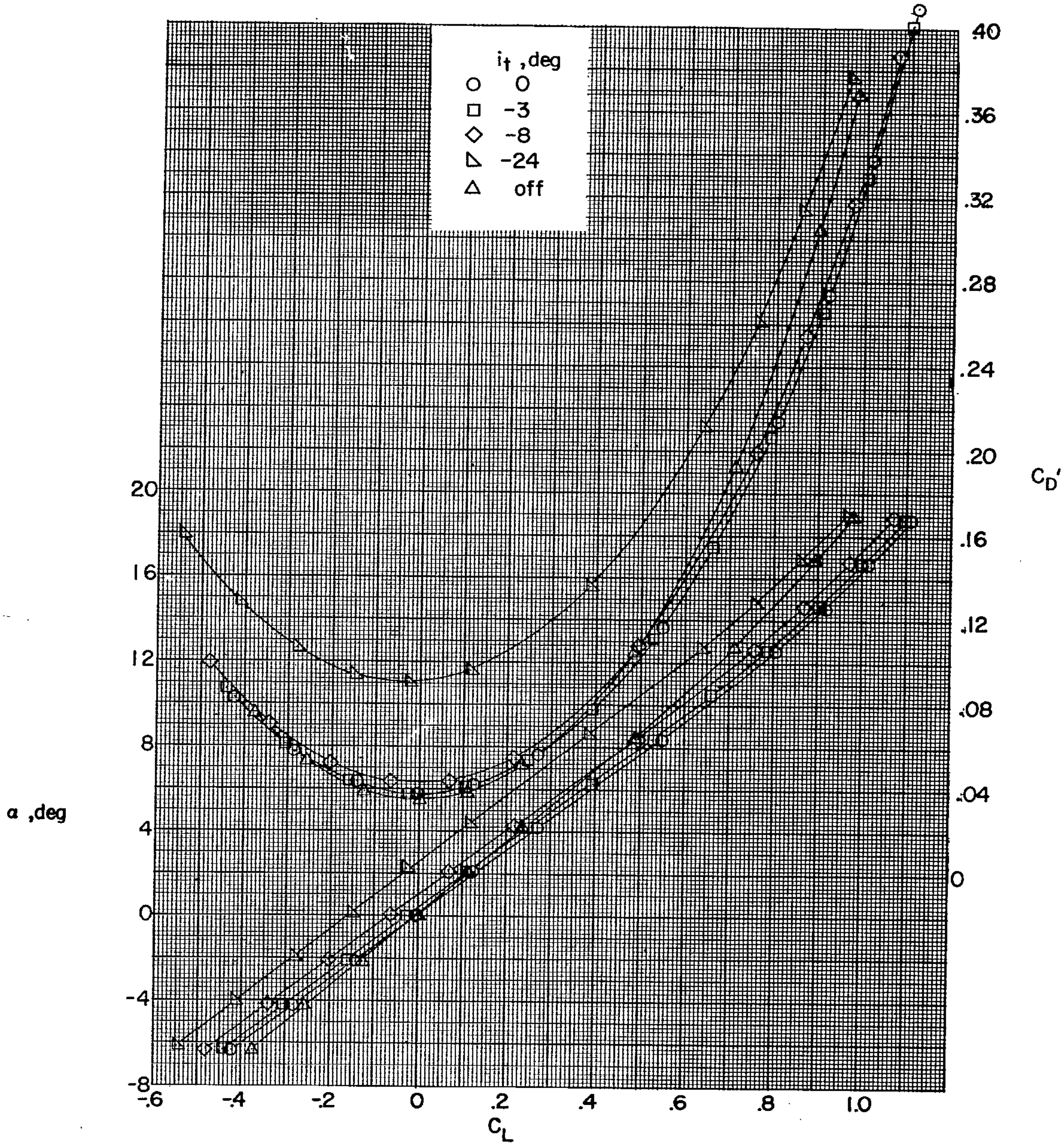
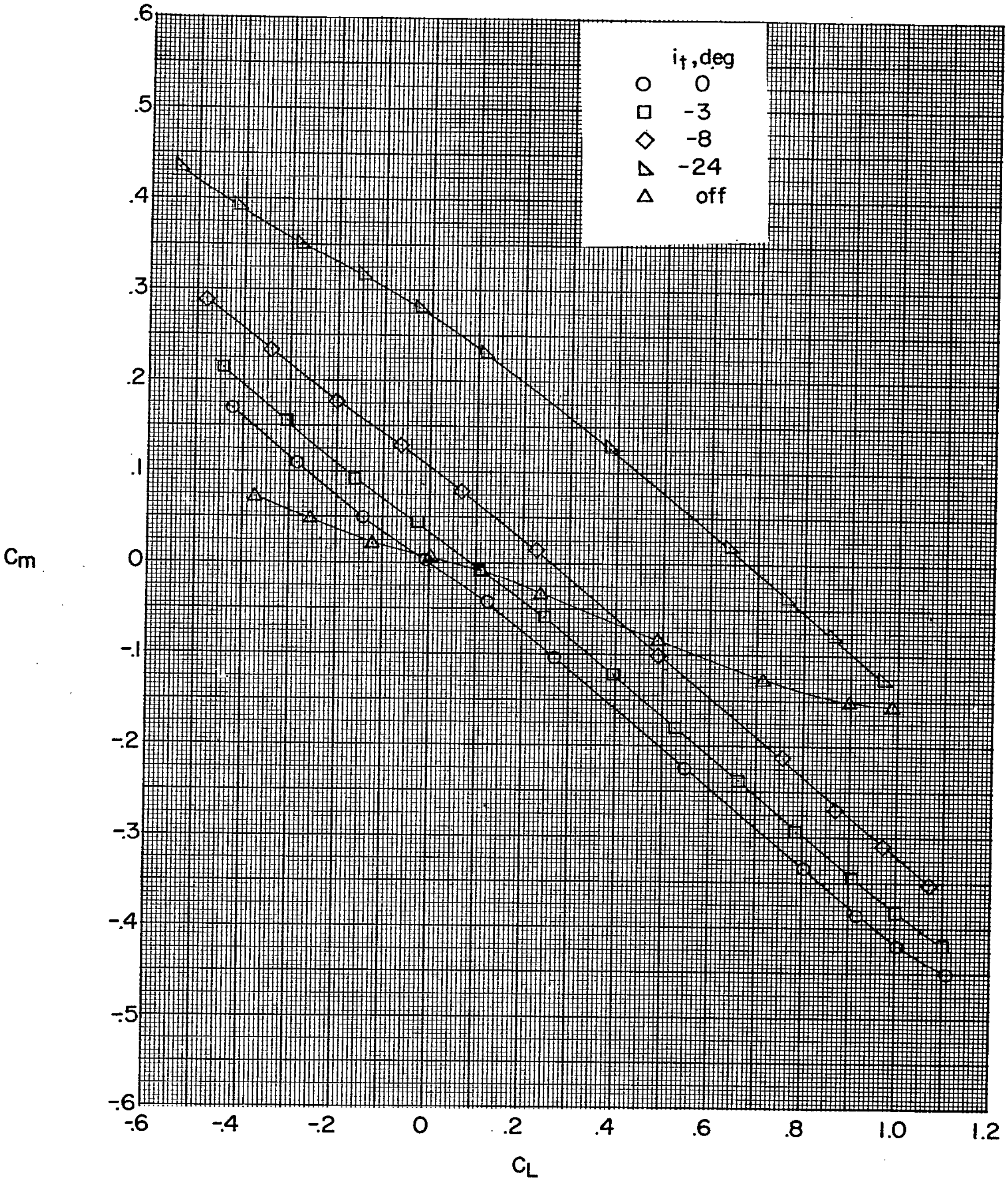


(a) Variation of drag coefficient and angle of attack with lift coefficient.

Figure 4.- Effect of horizontal tail on the longitudinal aerodynamic characteristics of the revised model. M = 1.41.



(b) Variation of pitching-moment coefficient with lift coefficient.

Figure 4.- Concluded.

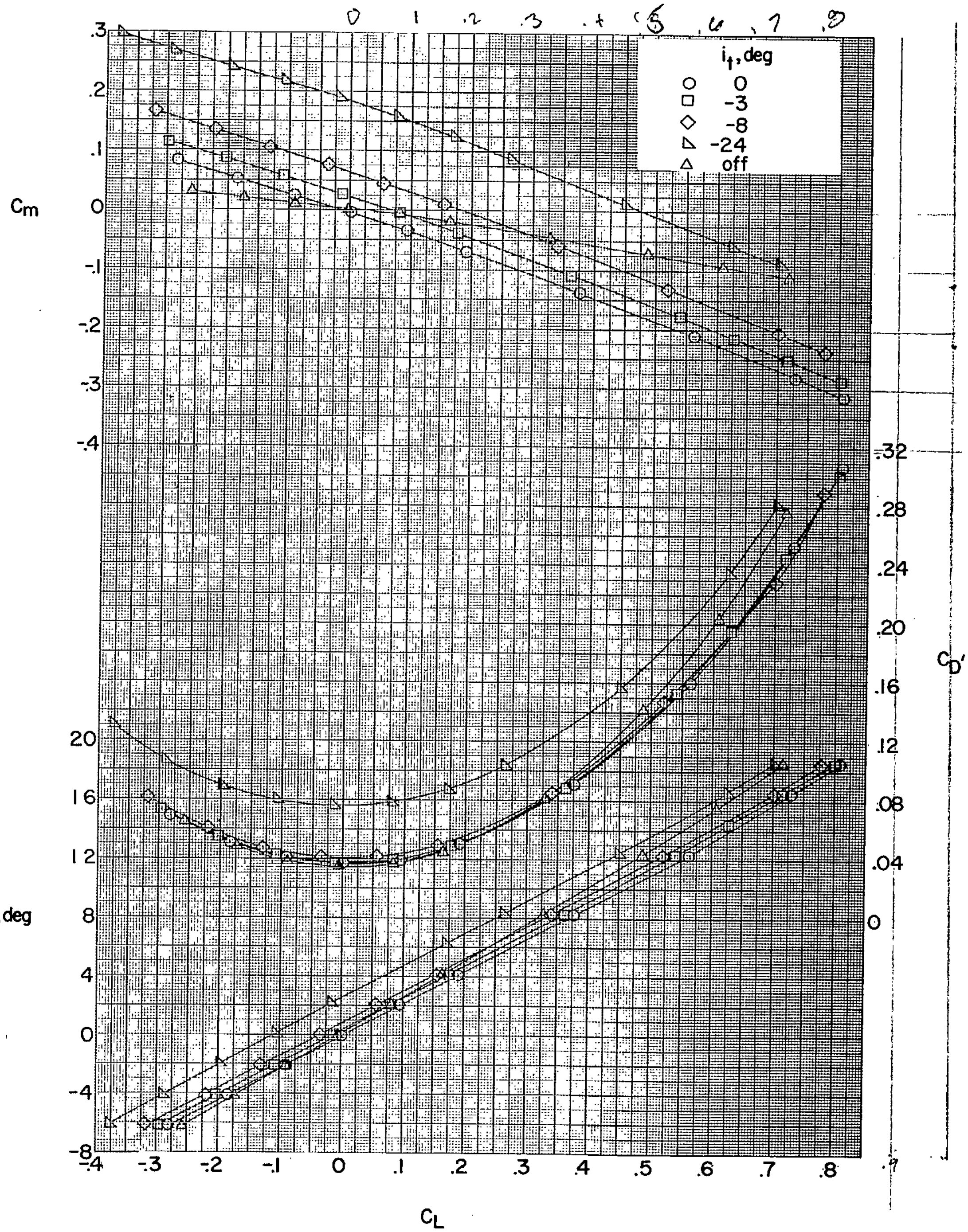


Figure 5.- Effect of horizontal-tail-on longitudinal aerodynamic characteristics of the revised model. M = 2.01.

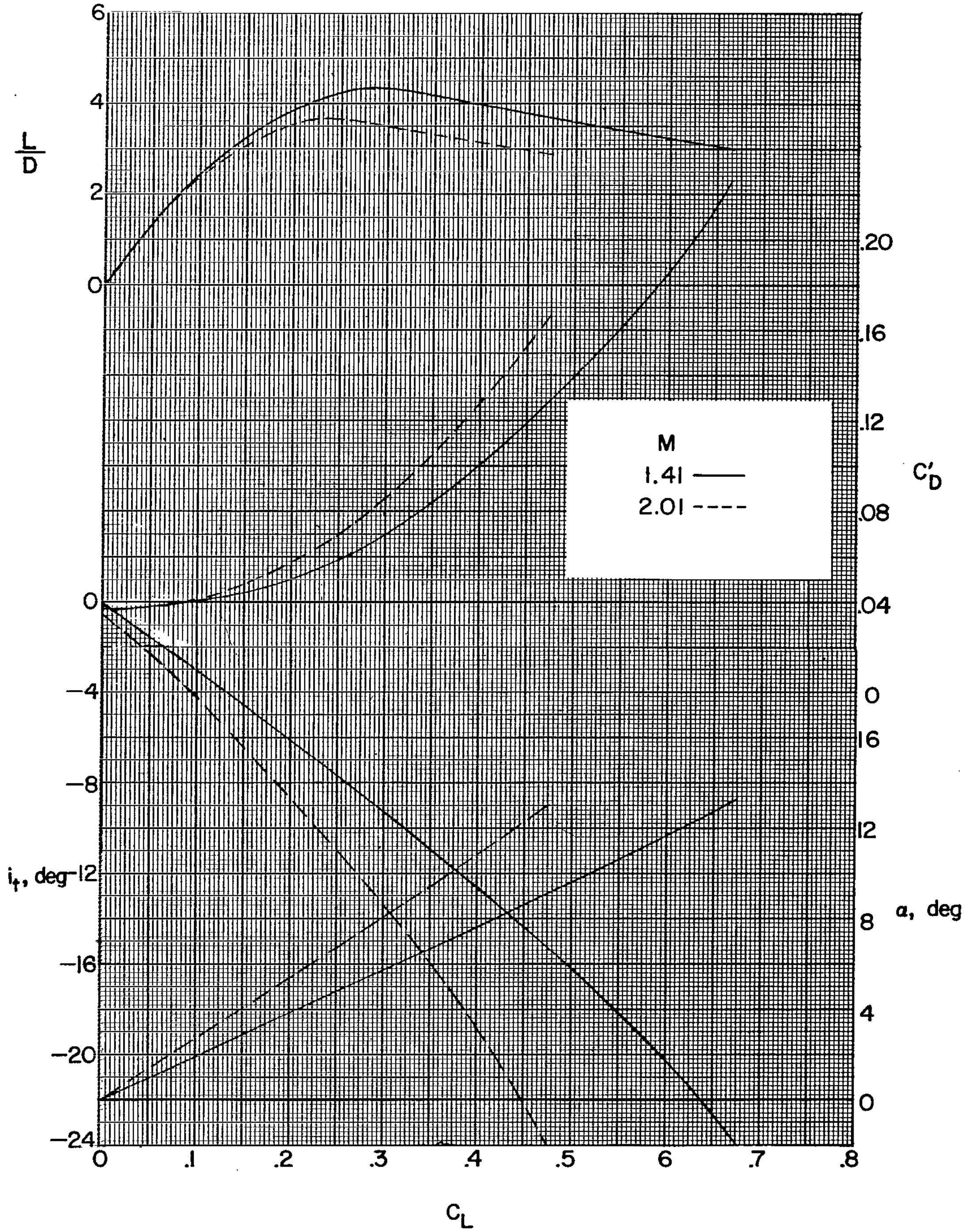


Figure 6.- Longitudinal trim characteristics of the revised model at M = 1.41 and M = 2.01.

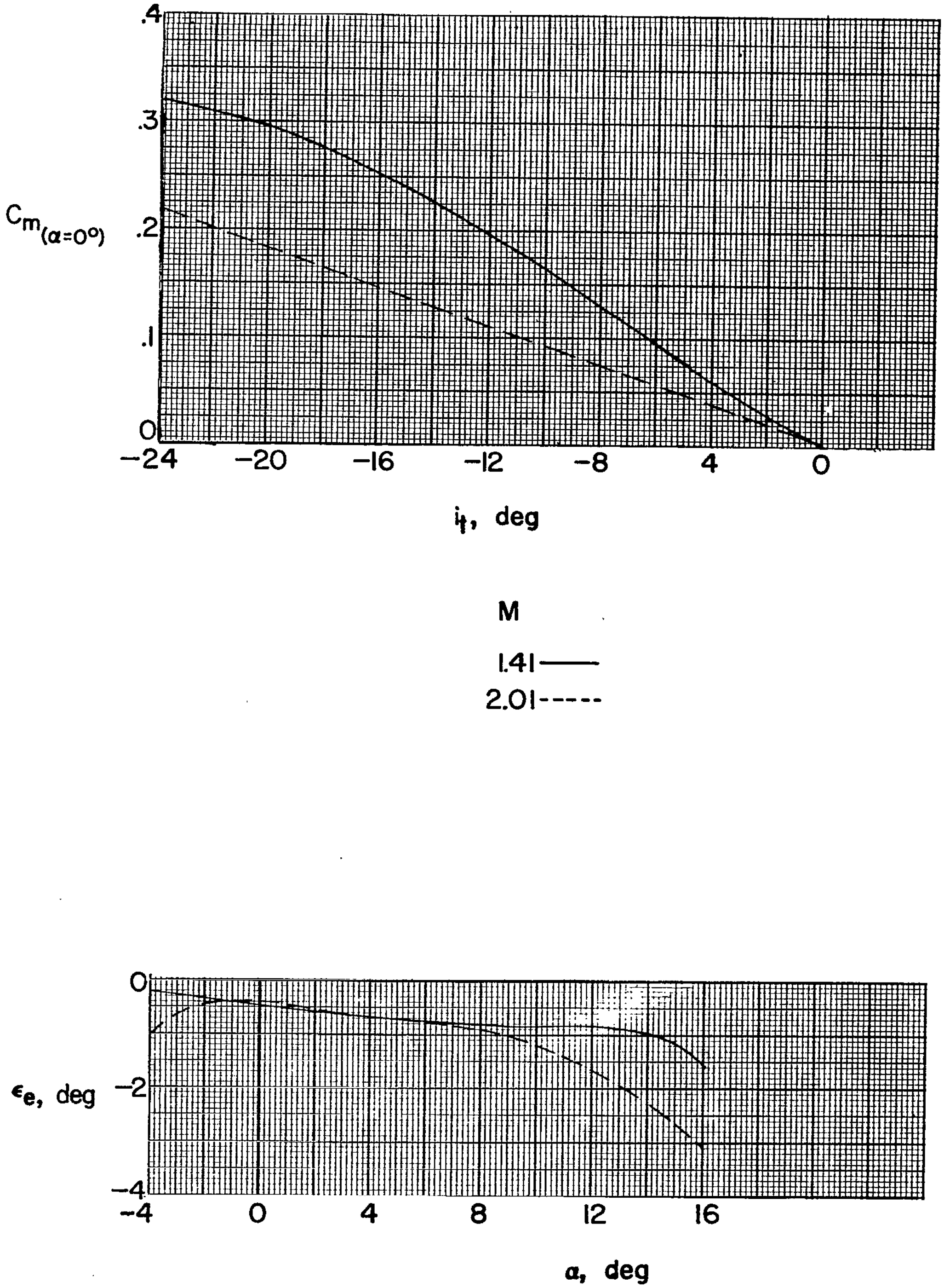


Figure 7.- Horizontal-tail effectiveness and effective downwash characteristics of revised model at $M = 1.41$ and $M = 2.01$.

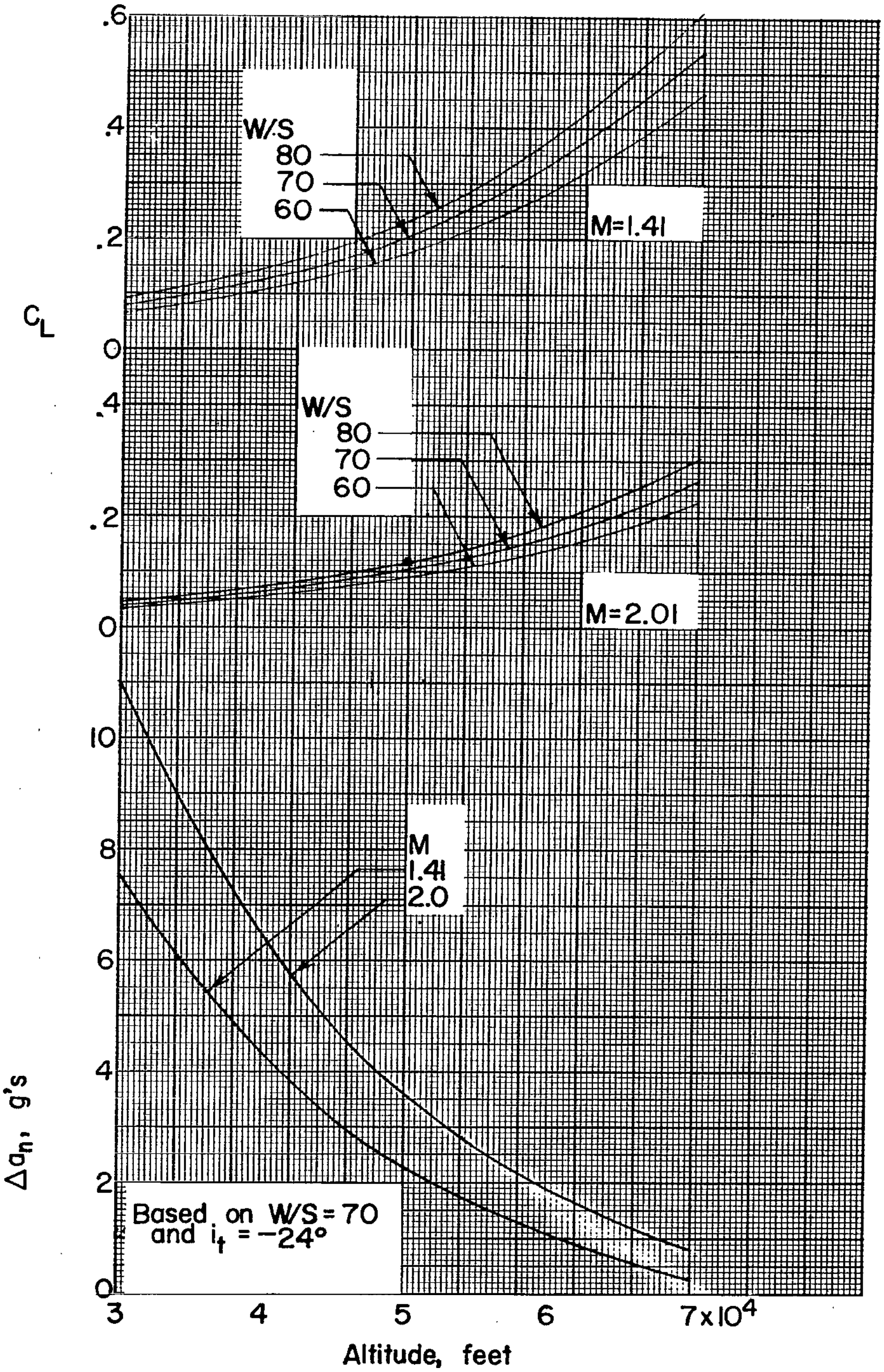
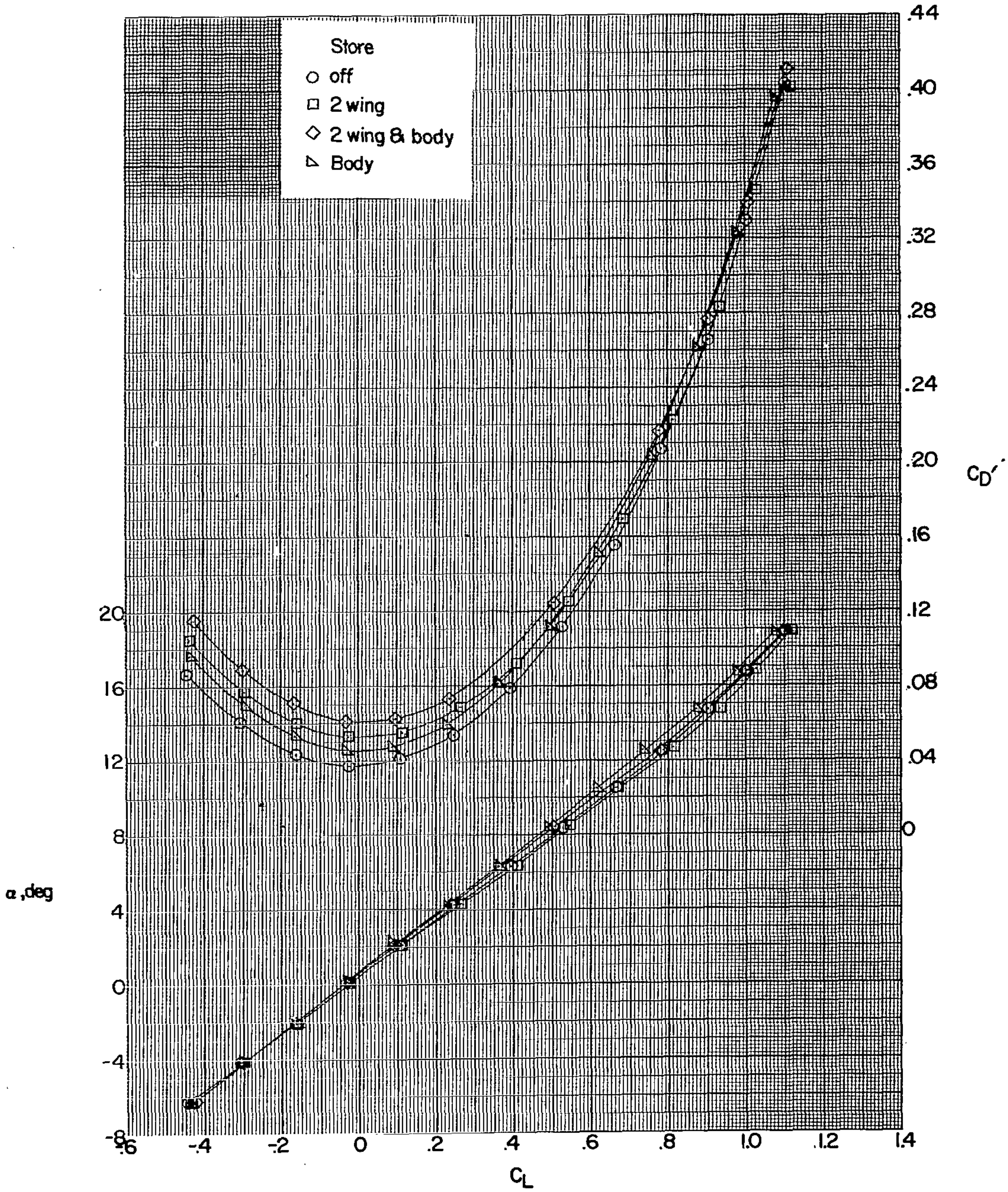
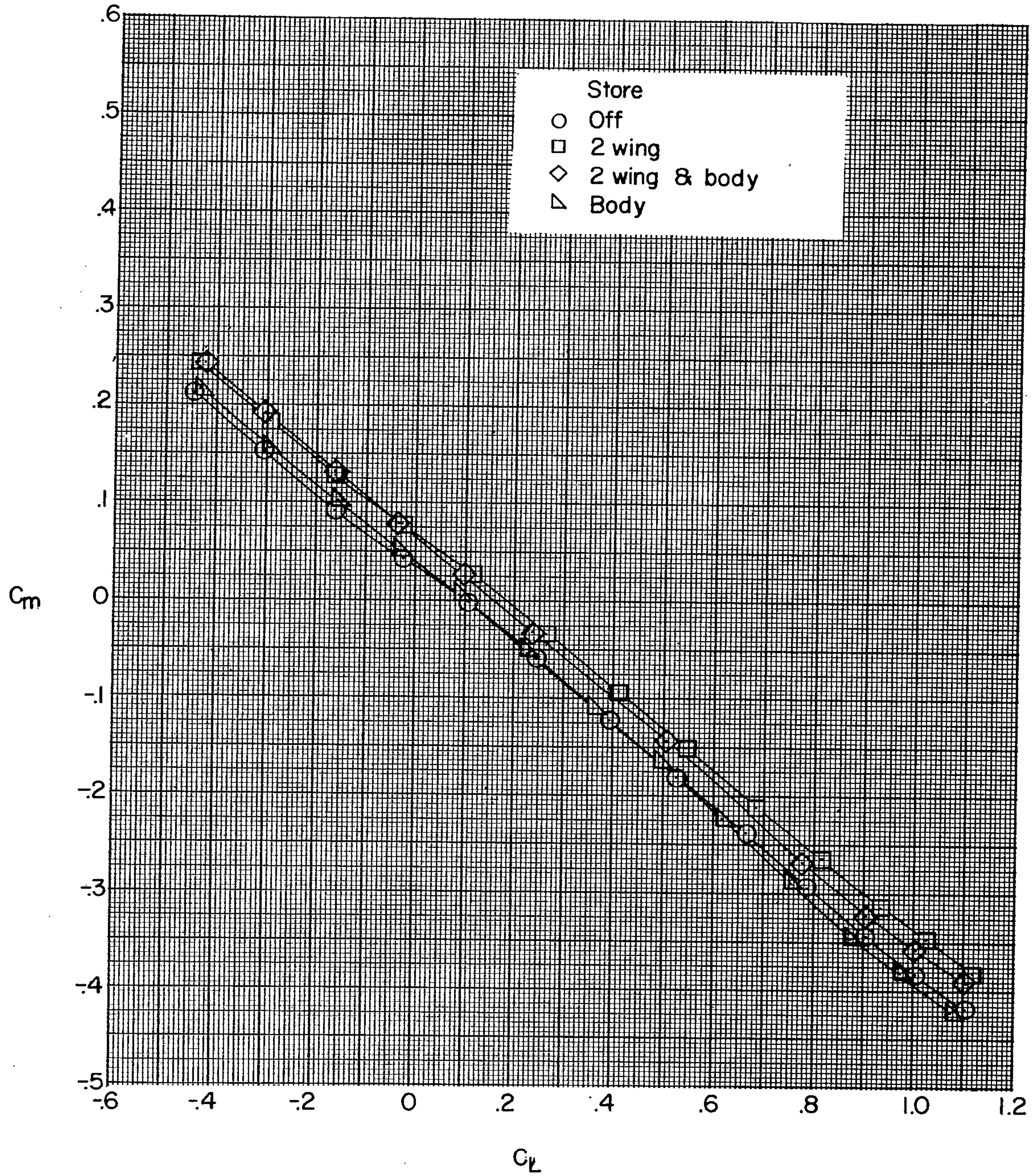


Figure 8.- Longitudinal control characteristics of revised model at $M = 1.41$ and $M = 2.01$.



(a) Variation of drag coefficient and angle of attack with lift coefficient.

Figure 9.- Effect of various store arrangements on the longitudinal aerodynamic characteristics of the revised model. $i_t = -3^\circ$; M = 1.41.



(b) Variation of pitching-moment coefficient with lift coefficient.

Figure 9.- Concluded.

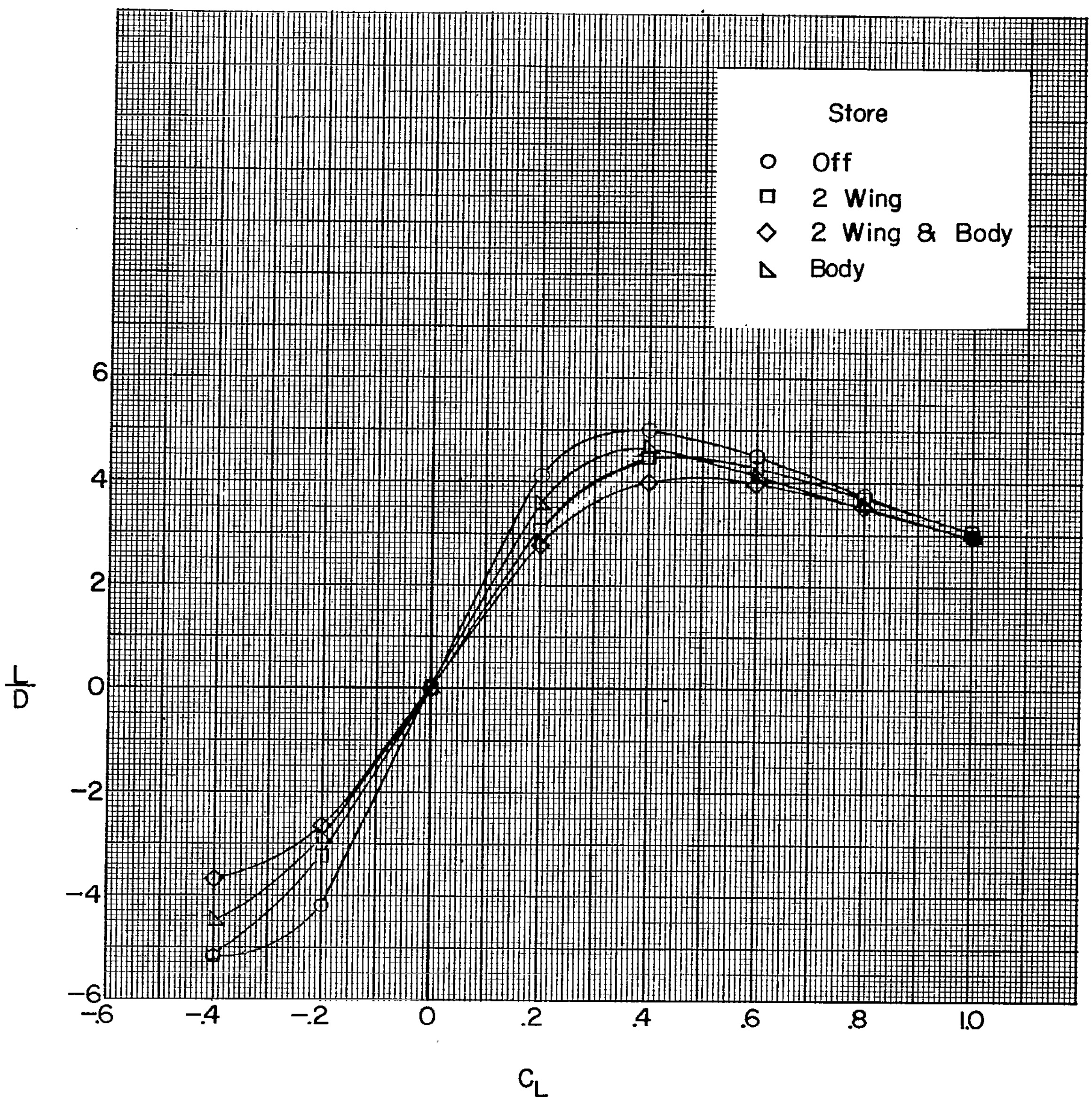
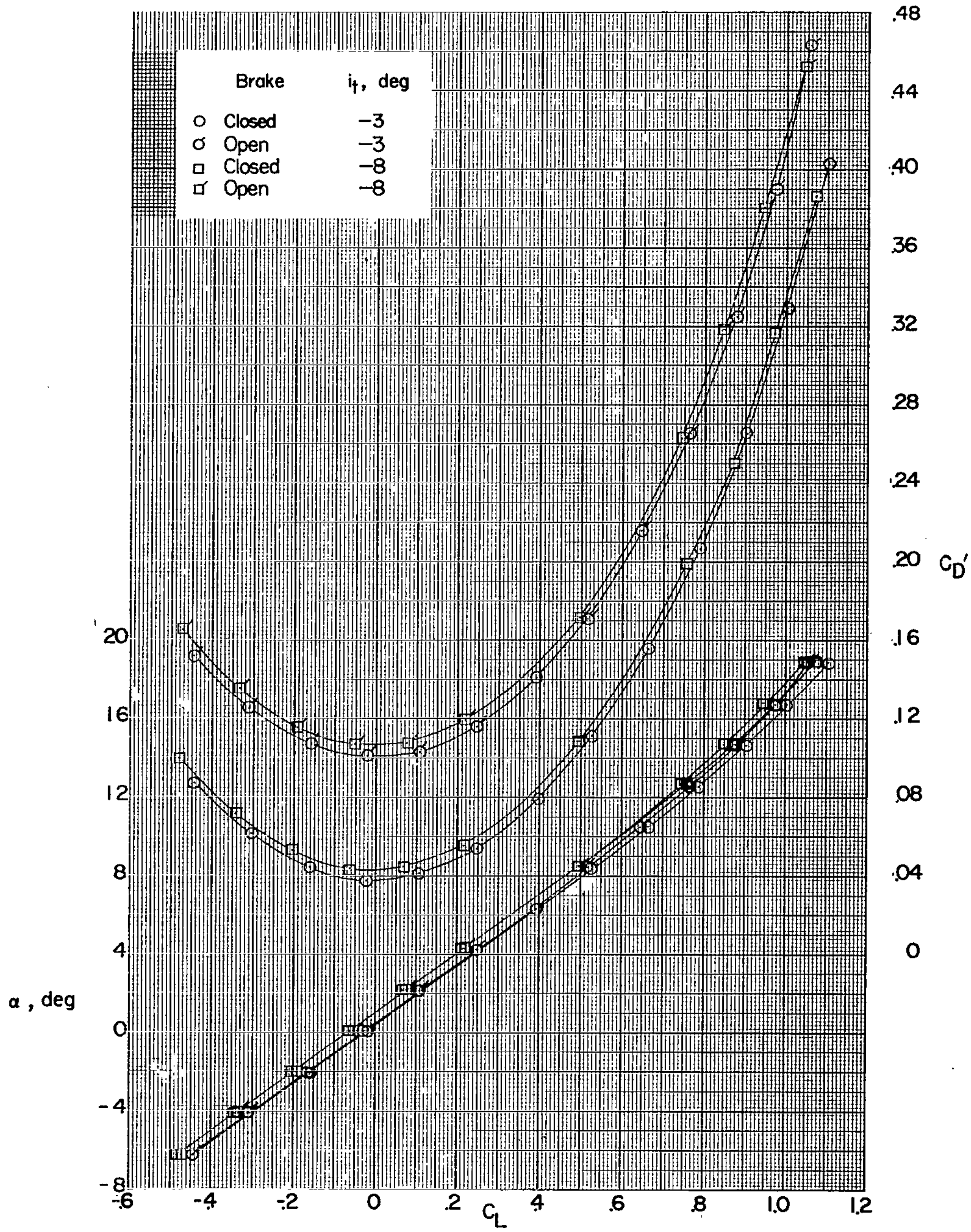
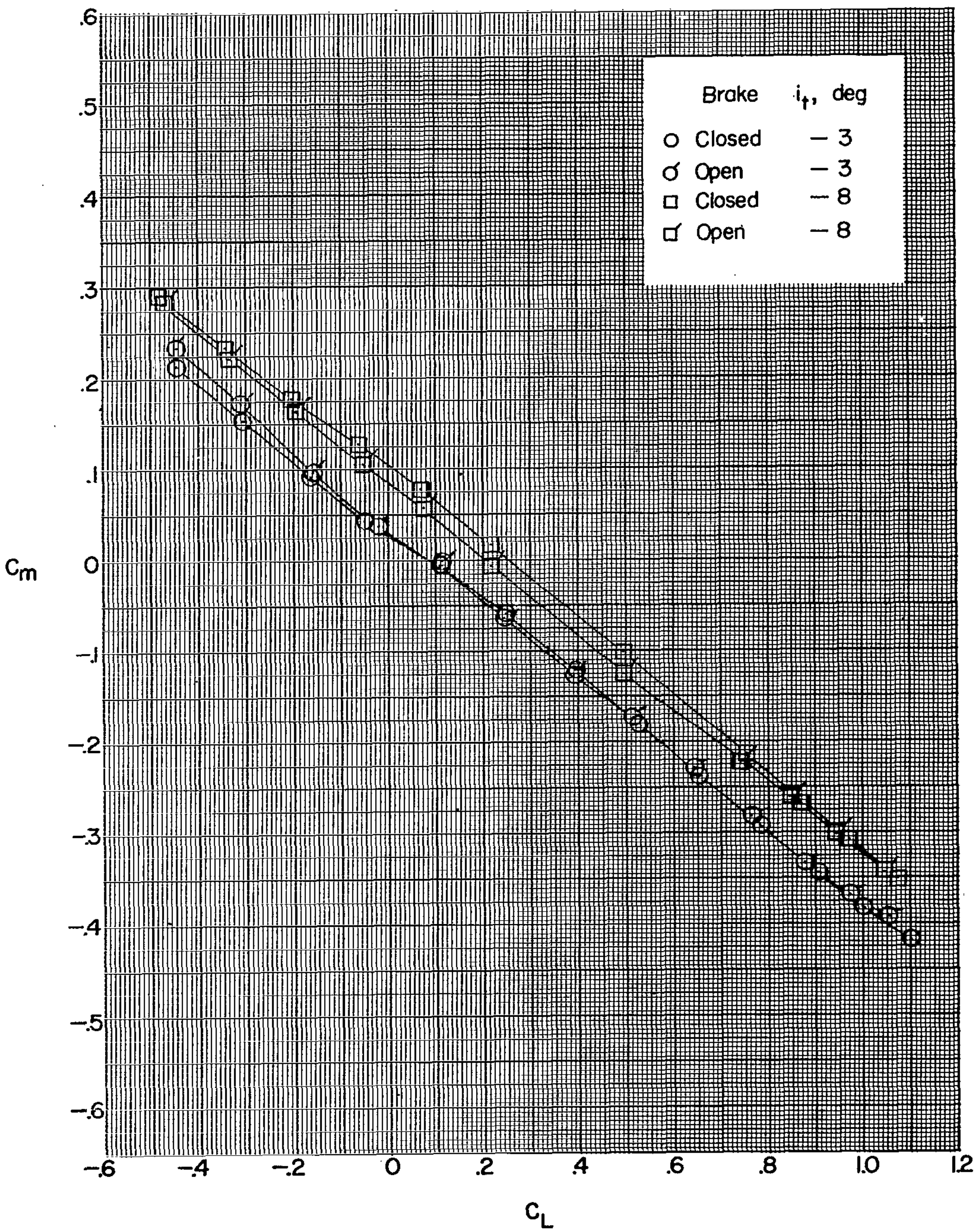


Figure 10.- Effect of various store arrangements on the lift-drag ratio of the revised model. $i_t = -3^{\circ}$; $M = 1.41$.



(a) Variation of drag coefficient and angle of attack with lift coefficient.

Figure 11.- Effect of dive-brake flaps on the longitudinal characteristics of the revised model. M = 1.41.



(b) Variation of pitching-moment coefficient with lift coefficient.

Figure 11.- Concluded.

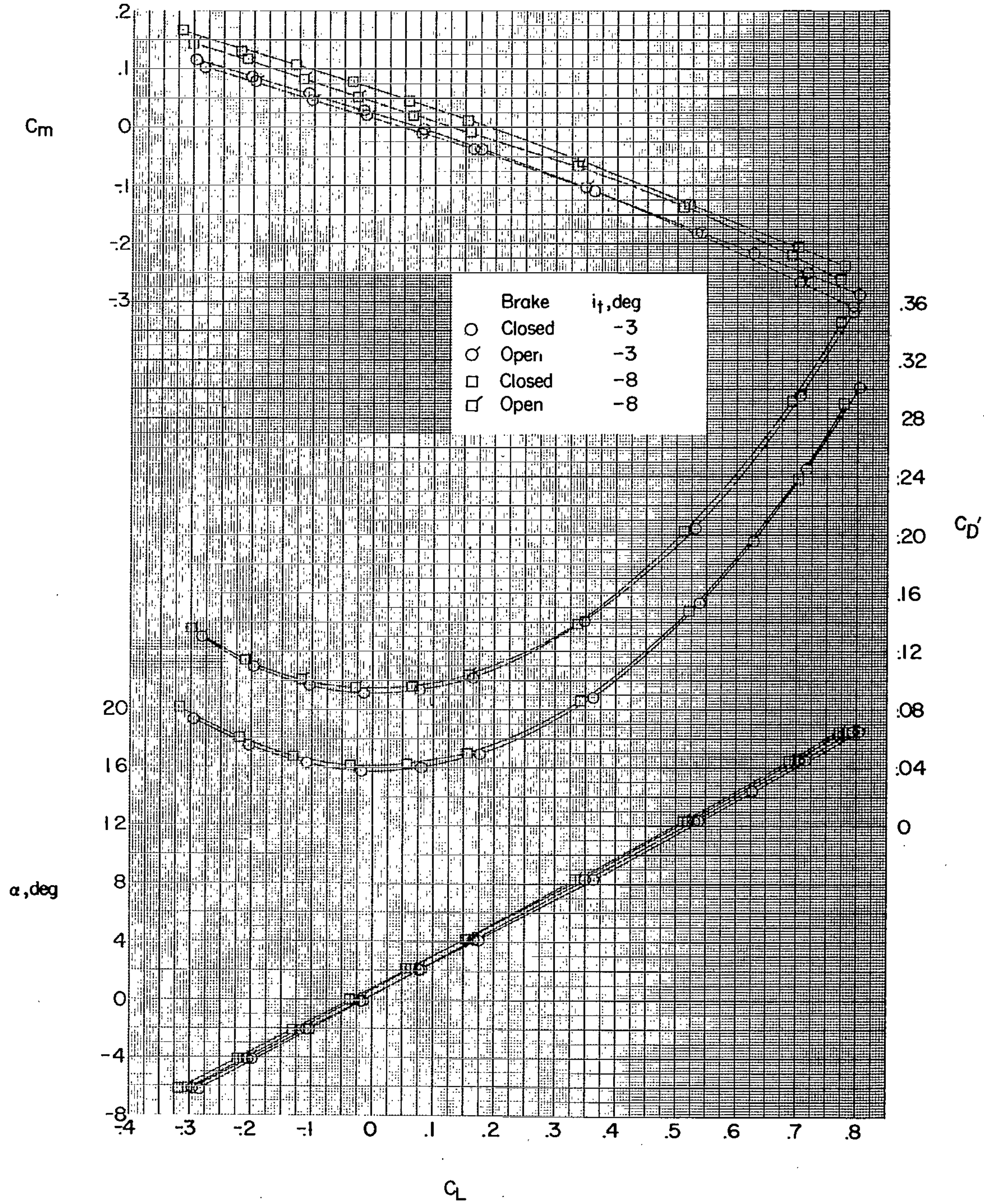


Figure 12.- Effect of dive-brake flaps on the longitudinal characteristics of the revised model. M = 2.01.

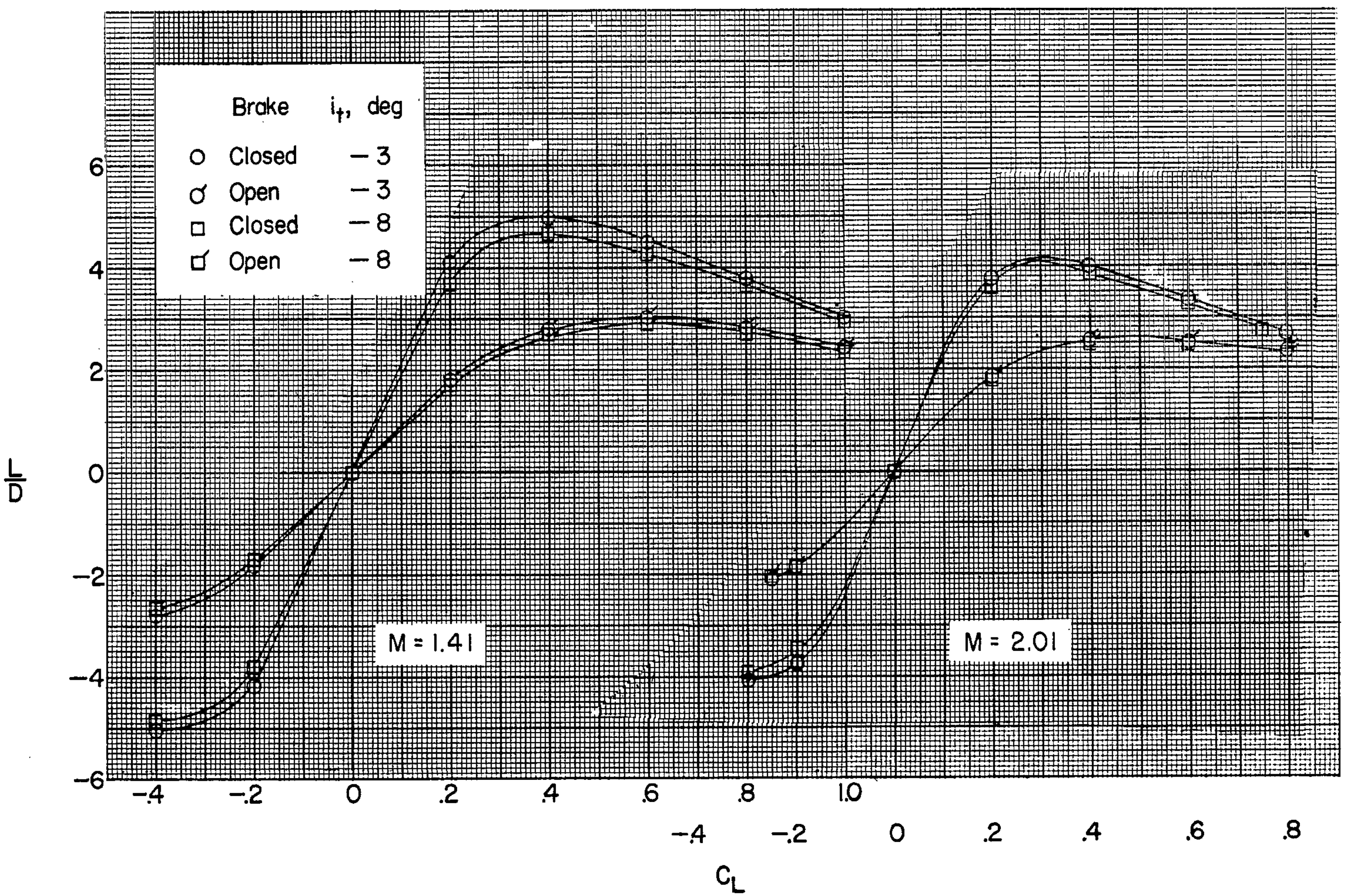
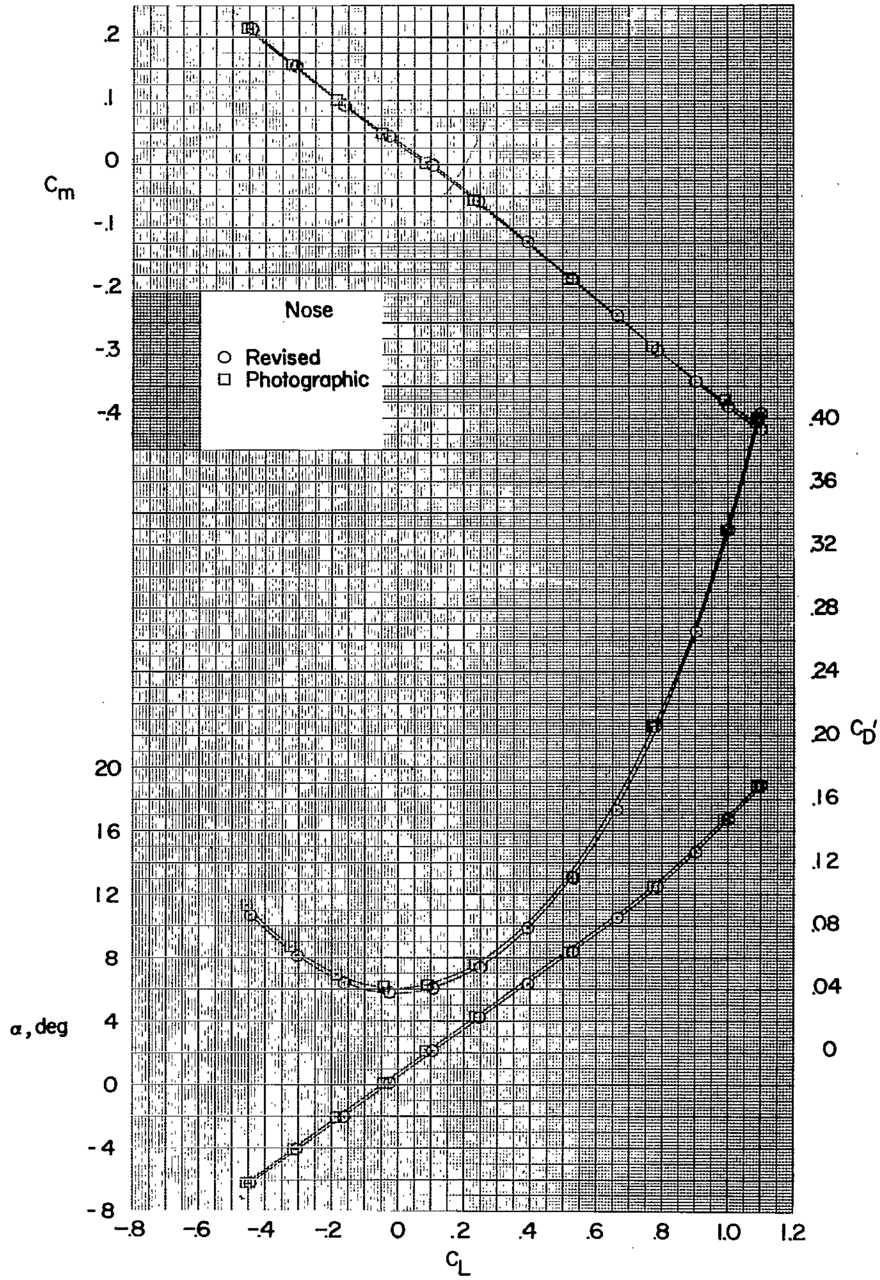
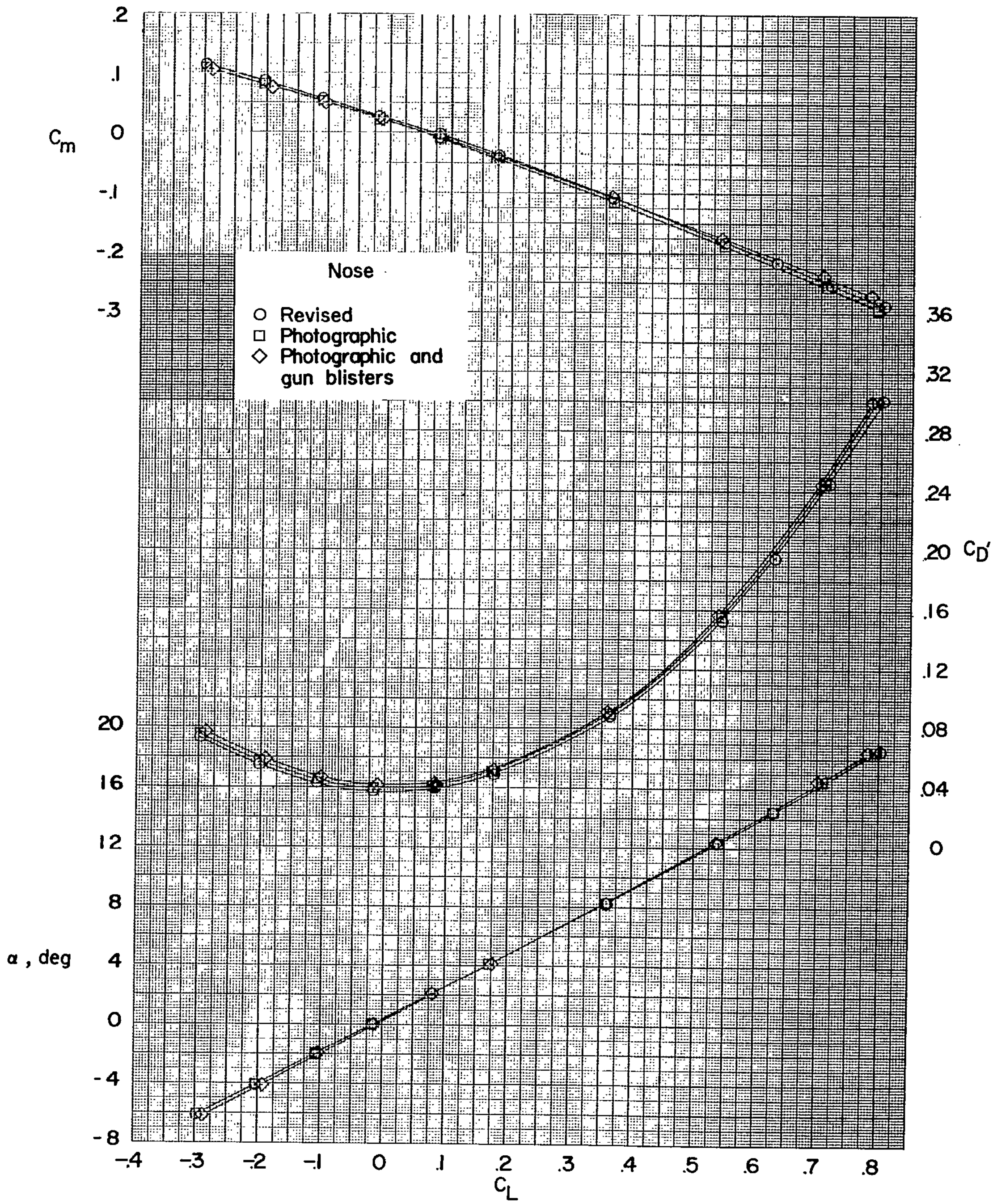


Figure 13.- Effect of dive-brake flaps on lift-drag ratio of the revised model at M = 1.41 and M = 2.01.



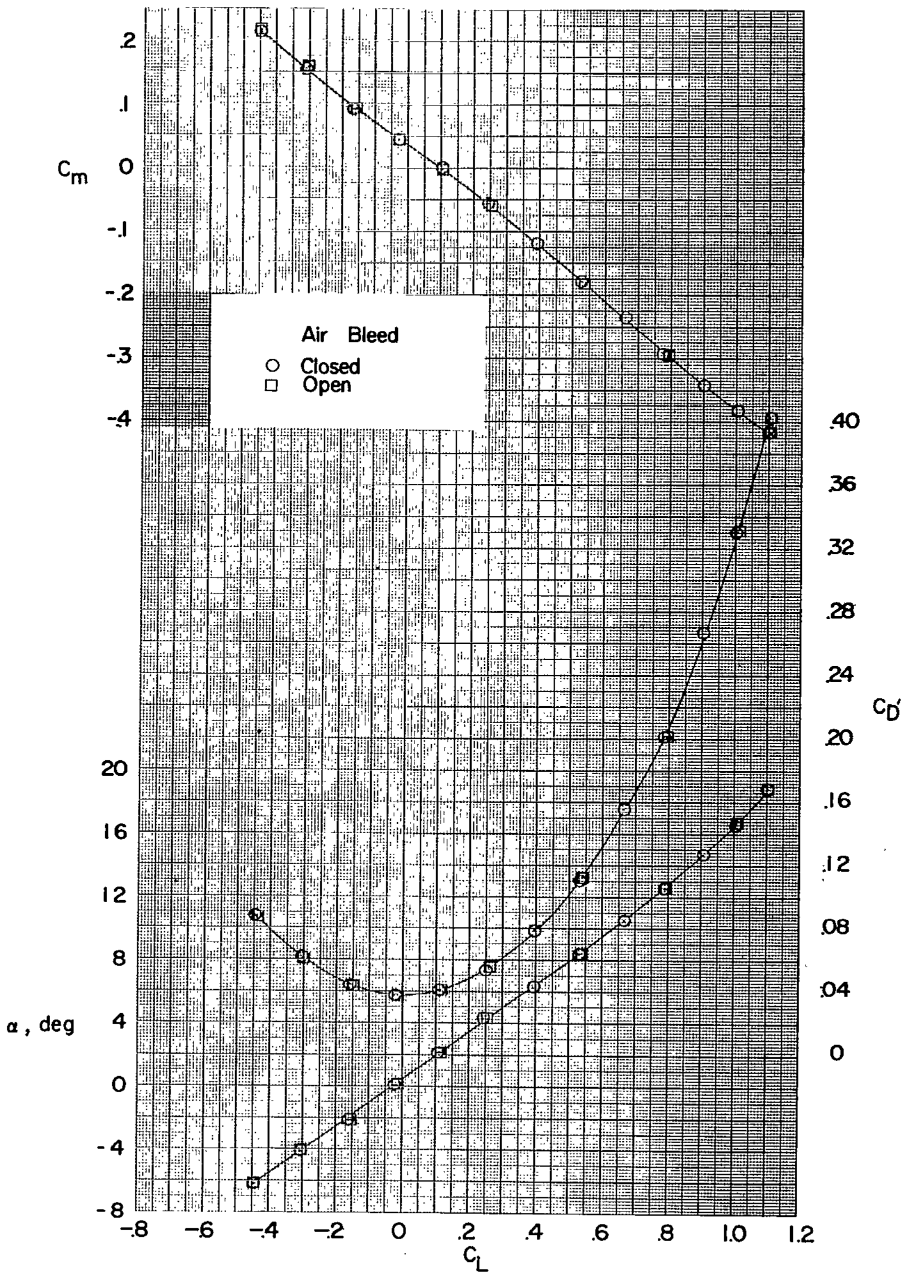
(a) M = 1.41.

Figure 14.- Effect of a forebody modification on the longitudinal aerodynamic characteristics of the revised model. $i_t = -3^{\circ}$.



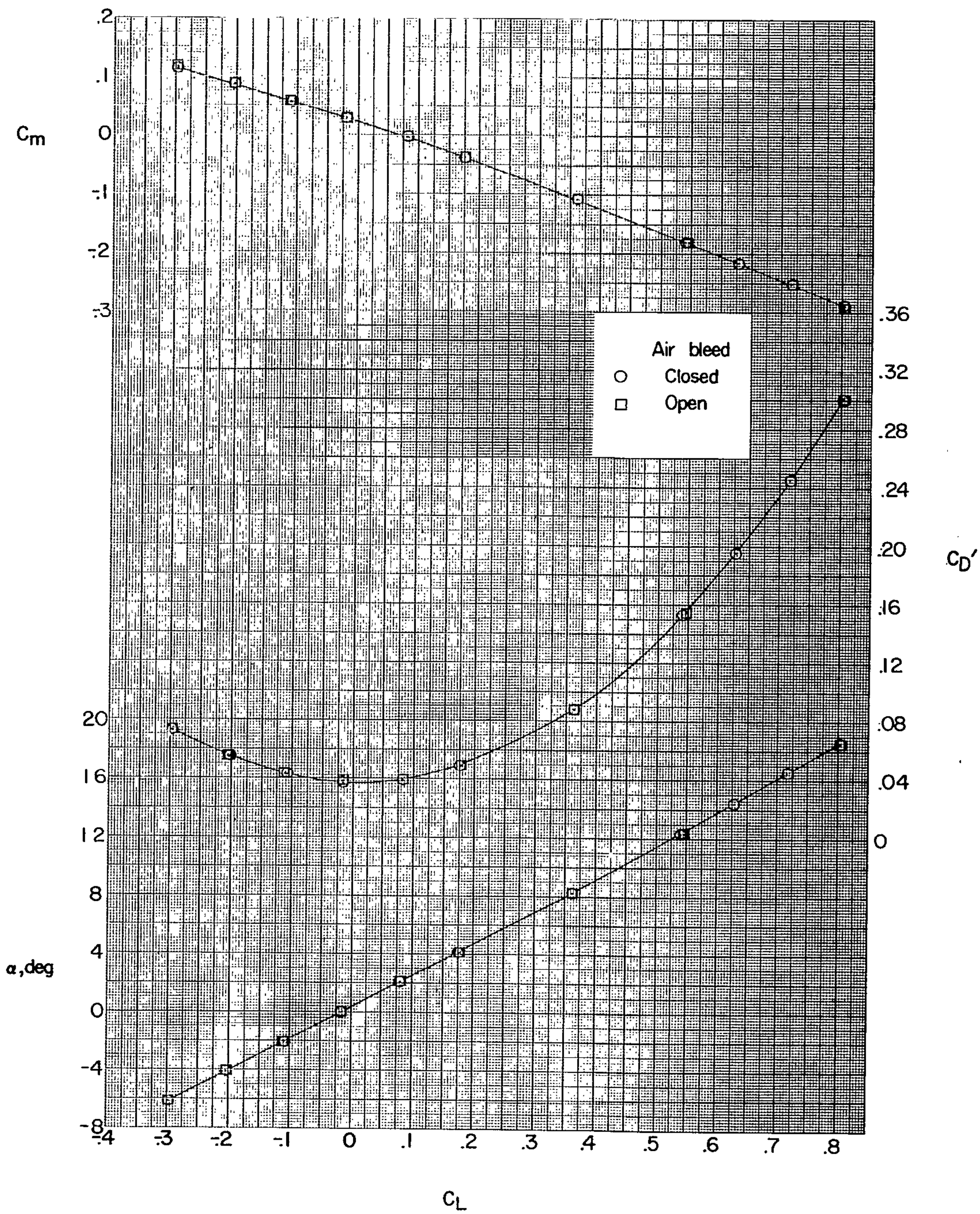
(b) M = 2.01.

Figure 14.- Concluded.



(a) M = 1.41.

Figure 15.- Longitudinal aerodynamic characteristics of the revised model. Air-bleed port open and closed; $i_t = -3^\circ$.



(b) M = 2.01.

Figure 15.- Concluded.

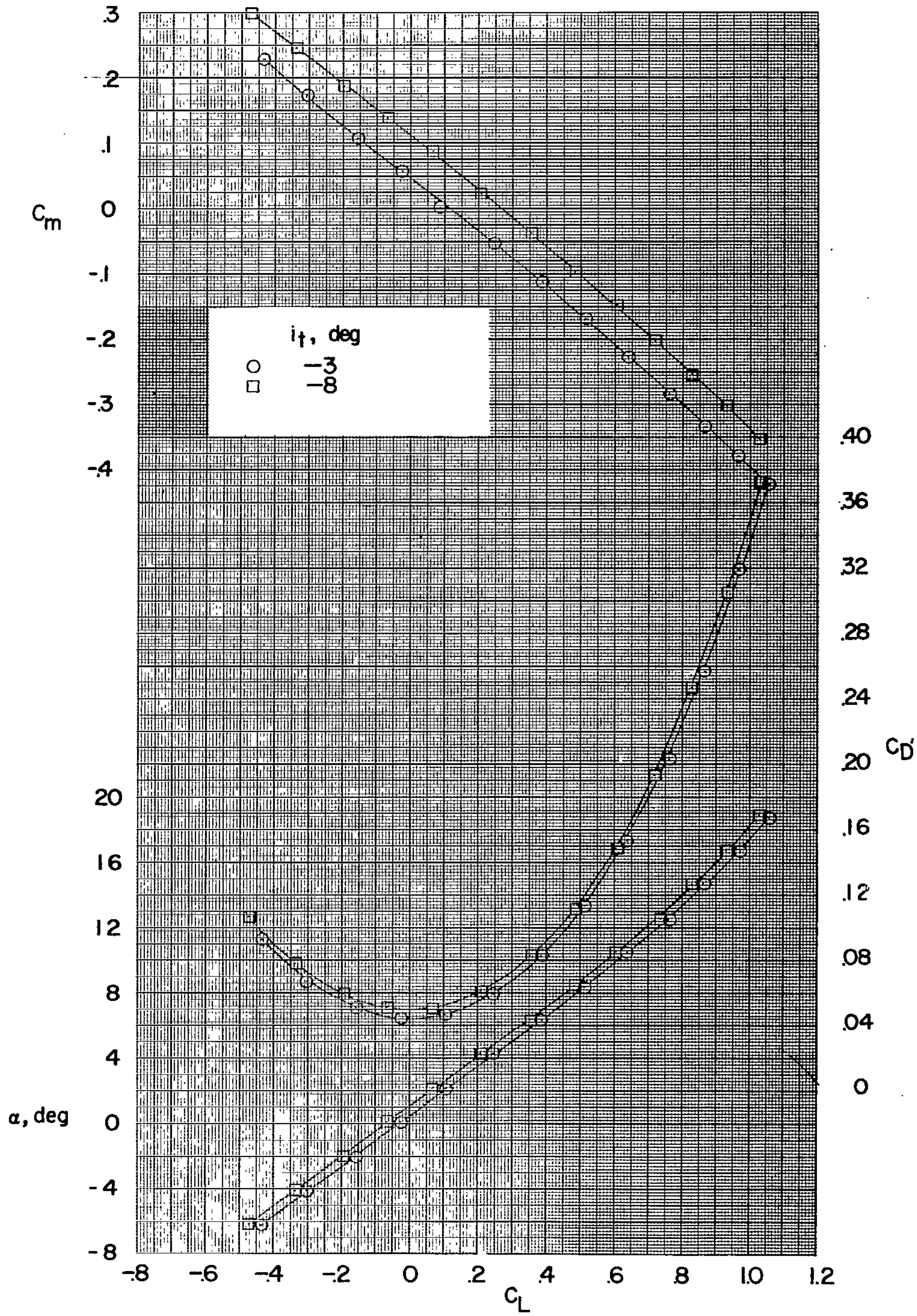


Figure 16.- Longitudinal aerodynamic characteristics of the original model. M = 1.41.

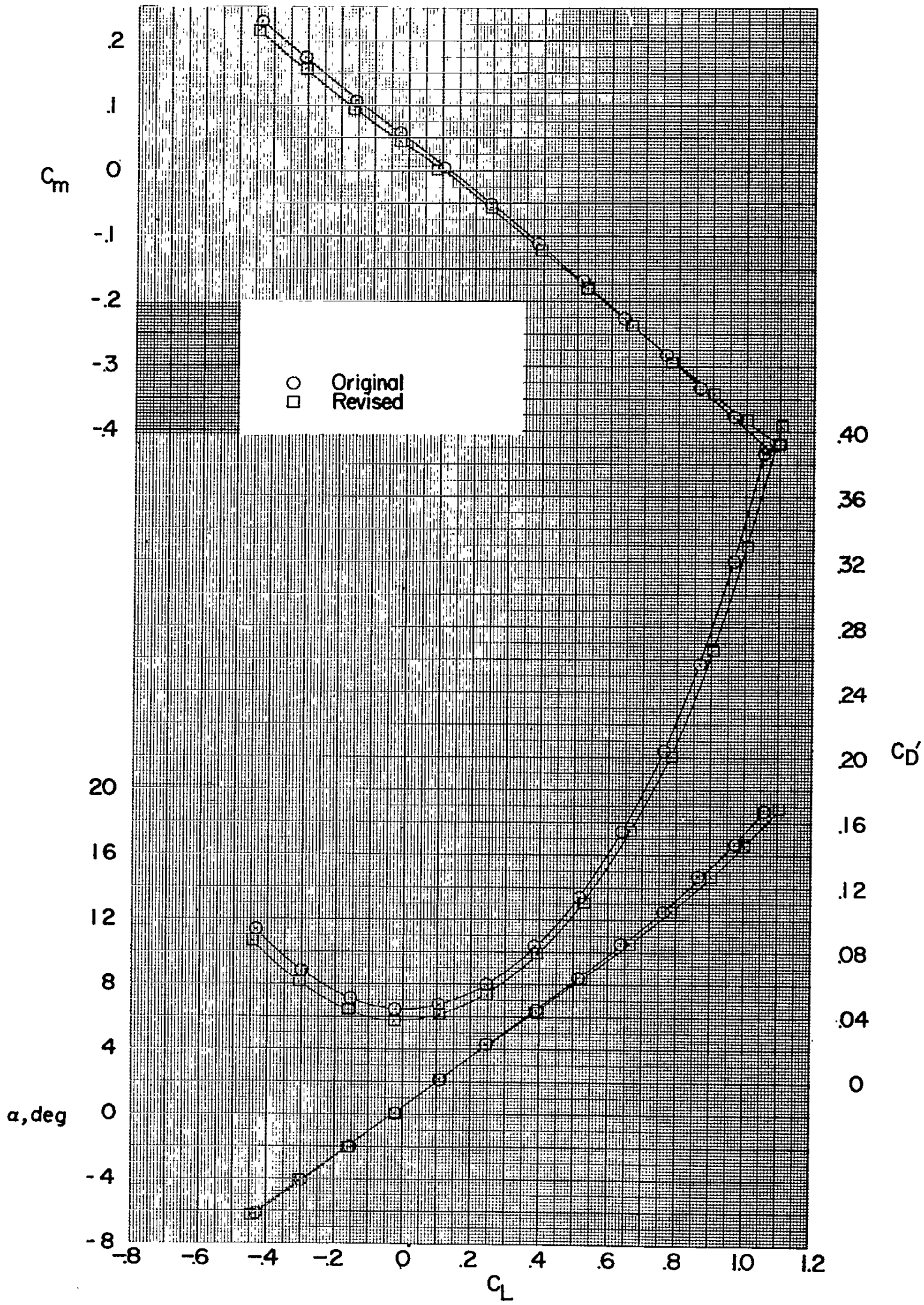


Figure 17.- Comparison of longitudinal aerodynamic characteristics of original and revised model. $i_t = -3^{\circ}$; M = 1.41.

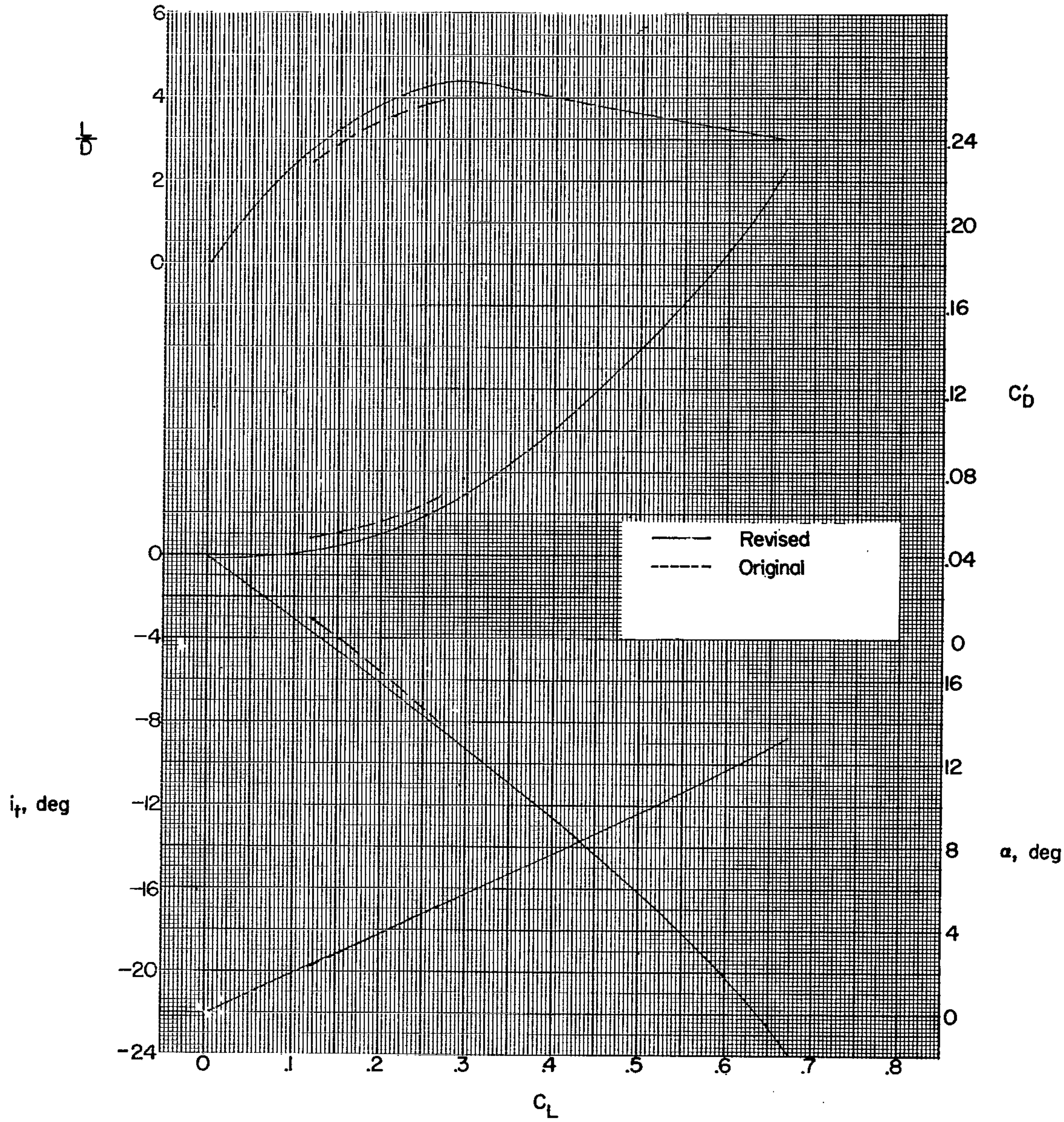
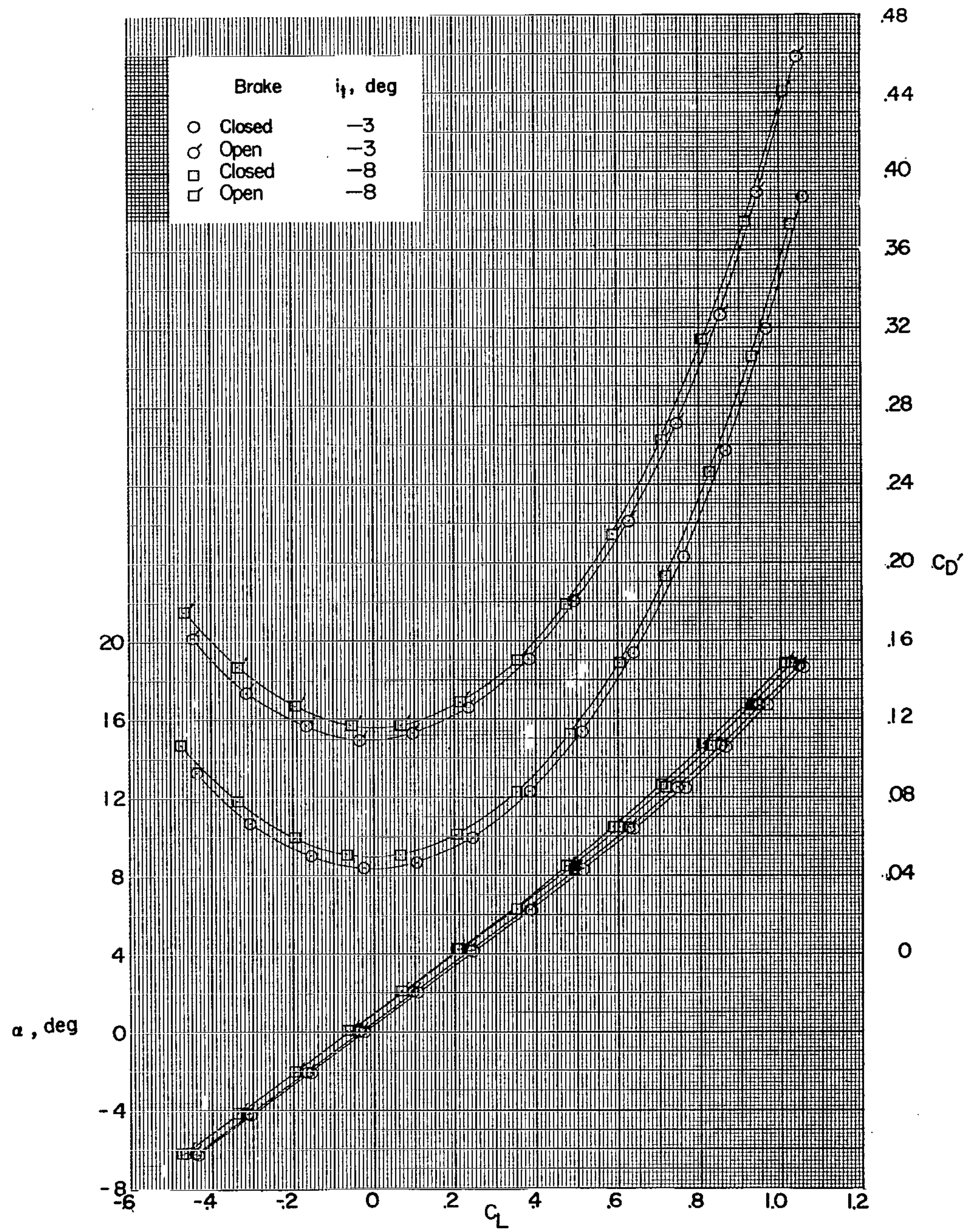
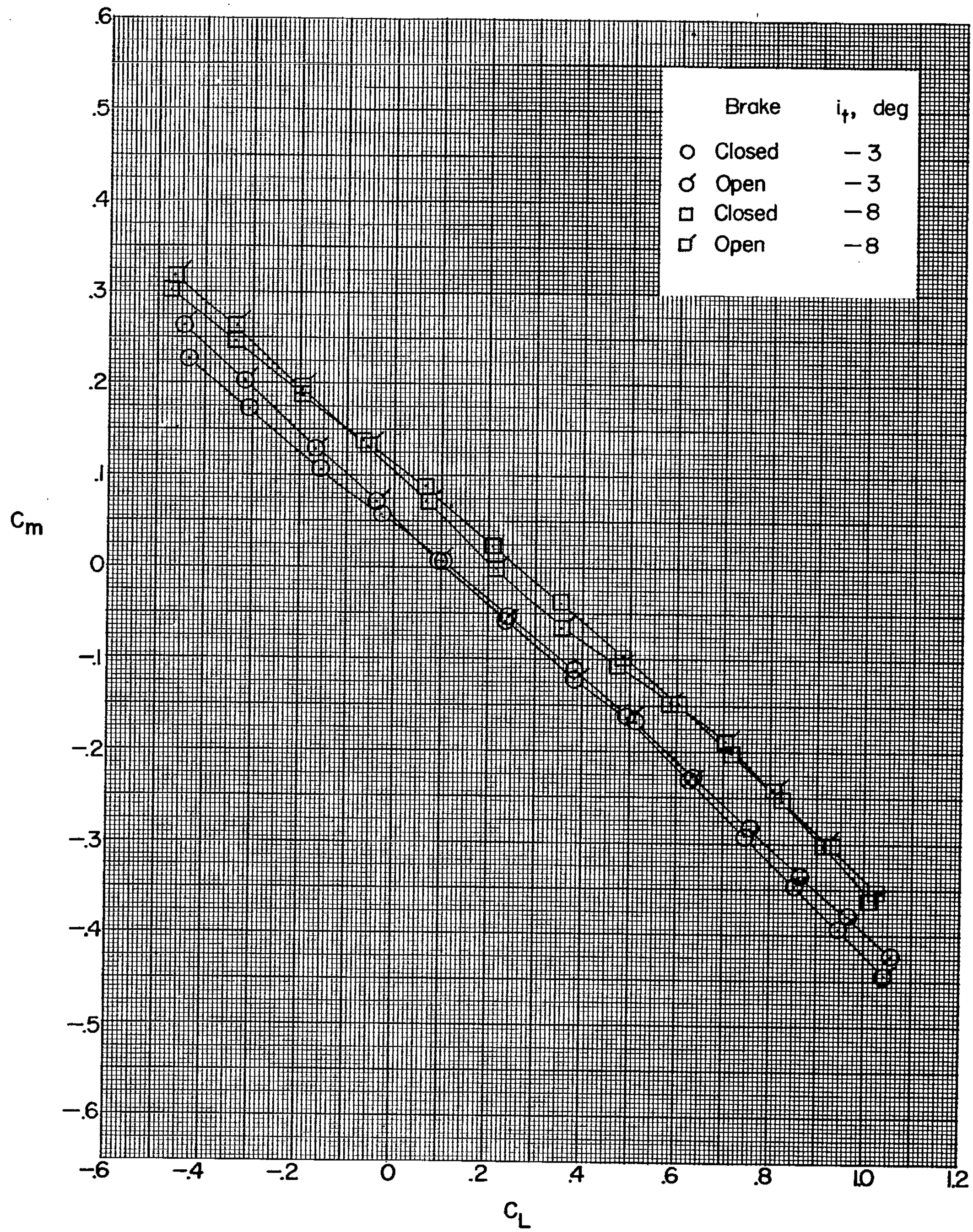


Figure 18.- Effect of model revisions on the longitudinal trim characteristics. M = 1.41.



(a) Variation of drag coefficient and angle of attack with lift coefficient.

Figure 19.- Effect of dive-brake flaps on the longitudinal characteristics of the original model. M = 1.41.



(b) Variation of pitching-moment coefficient with lift coefficient.

Figure 19.- Concluded.

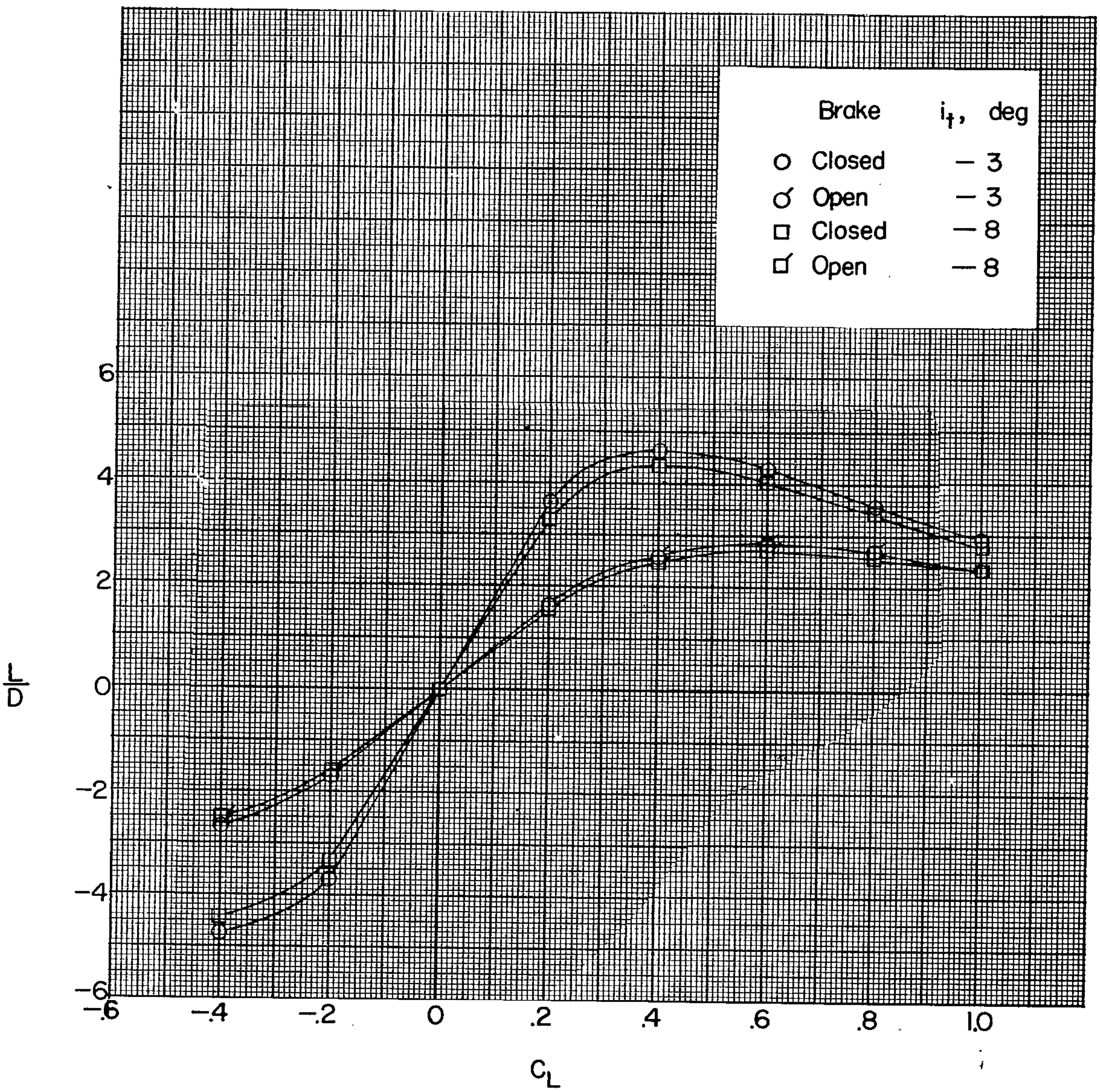


Figure 20.- Effect of dive-brake flaps on lift-drag ratio of the original model. M = 1.41.

INDEX

Subject	Number
Tail-Wing-Fuselage Combinations - Airplanes	1.7.1.1.3
External Stores, Effects of - Airplanes	1.7.1.1.5
Airplanes - Specific Types	1.7.1.2
Stability, Longitudinal - Static	1.8.1.1.1
Control, Longitudinal	1.8.2.1
Air Brakes	1.8.2.4

ABSTRACT

This paper includes the results of an investigation which has been conducted in the Langley 4- by 4-foot supersonic pressure tunnel to determine the longitudinal aerodynamic characteristics of various configurations of a 1/22-scale model of the Republic F-105 airplane at Mach numbers of 1.41 and 2.01. In addition, the effects of dive-brake flaps, open duct air-bleed port, and several externally mounted stores are shown. The effects of model revisions which included a lengthened fuselage, a relocated canopy, a contoured fuselage afterbody, an enlarged vertical tail, and a change in inlet geometry are shown for a Mach number of 1.41.